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STUDIES ON SEED DORMANCY AND GERMINATION,
GROWTH AND DEVELOPMENT, AND CONTROL
OF TARTARY BUCKWHEAT (FAGOPYRUM TATARICUM (L.) GAERTN.)


William H. Vanden Born

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April, 1958

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STUDIES ON SEED DORMANCY AND GERMINATION, GROWTH
AND DEVELOPMENT, AND CONTROL
OF TARTARY BUCKWHEAT (FAGOPYRUM TATARICUM (L.) GAERTN.)

A DISSERTATION
SUBMITTED TO THE FACULTY OF GRADUATE STUDIES
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by

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ABSTRACT

The objective of this work was to study characteristics of growth and development of the prohibited weed Tartary buckwheat (Fagopyrum tataricum (L.) Gaertn.), and the effects on plant and seed of various treatments and environmental conditions.

The progress of after-ripening of Tartary buckwheat seeds, which are dormant when newly mature, was observed under different conditions of storage, and the effects of various physical and chemical treatments on dormancy were studied.

Germination of fresh seeds was increased slightly by removal of both pericarp and seed coat. The seed coat did play some part in dormancy, but its relationship to that condition could not be reduced to any one single factor such as impermeability to water or the presence of a growth-inhibiting substance.

The after-ripening process took place very slowly at low temperature, and was accelerated by higher temperature to a maximum at approximately 80° C. To overcome dormancy heating seeds to 60° C. in a closed container was as effective as drying them at 80° C. in an open one. The loss of dormancy was much more strongly affected by temperature than by moisture content of the seeds. There was evidence for an optimum moisture content for the after-ripening of Tartary buckwheat seeds at room temperature.

The progress of germination and emergence was observed at different temperatures; from different depths in the soil; and at

different times during the growing season. Seedlings were produced under a wide variety of conditions.

Flowering began five to six weeks after planting and the first seeds matured four to five weeks later. The flowering habit of the species is indeterminate and flower development and seed production continued until stopped by frost in the fall.

If buckwheat plants in the flower-bud stage were sprayed with low volatile (LV) 2,4-D, a number of abnormal seeds was produced. These seeds were equal in viability to normal-appearing seeds, and on planting produced plants which were normal in all respects.

For control of Tartary buckwheat there was no advantage in using two applications of herbicide, twelve days apart, rather than a single application at a correspondingly higher rate. At comparable rates LV 2,4-D was more effective than 2,4-D, especially at the later growth stages, and both were much superior to MCPA for the control of Tartary buckwheat.

Under the conditions of the experiment up to fifty buckwheat plants per square yard had not affected, during the time before spraying, the ultimate yield of barley. On sprayed plots there was a balancing effect between herbicidal injury to the grain, and decreased weed competition. The effect of the interaction between these two factors was manifested in the yield of grain.

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INTRODUCTION

Farmers throughout the world each year suffer enormous losses directly or indirectly due to the presence of weeds in their crops. In order to reduce these losses, growth of the weedy plants must be checked, or if possible and practical, these plants must be eradicated. The process of eradication, whether by chemical or by cultural methods, can be carried out effectively only after obtaining a sufficient amount of knowledge about the growth habits and developmental processes of the species present.

Some of this knowledge may be obtained from extensive general observations of a wide variety of weedy plants under different conditions, but it seems probable that a more intensive study in which the characteristics of one species at a time are carefully investigated, will yield the most accurate and valuable information.

Among the particular problems in Alberta and parts of Manitoba, Tartary buckwheat (Fagopyrum tataricum (L.) Gaertn.) has assumed increasing importance as a weed in recent years. Wheat delivered to Alberta elevators has been reported to contain up to 30 percent Tartary buckwheat (16). The presence of Tartary buckwheat seeds in wheat or malting barley seriously lowers the commercial grade of these products, mainly because of the difficulty of separating these seeds from grain. The weed is classified as a "prohibited noxious weed" in western Canada, and under the Canada Seeds Act no grain containing seeds of this species may be sold as seed (51).

The considerations presented above, and the resistance of Tartary buckwheat to chemicals used in present day weed control methods led to the choice of this species as the subject of investigation. It was thought important and instructive to study seed dormancy and seed germination, and to observe characteristics of growth and development of the species as they are affected by various treatments and environmental conditions.

LITERATURE REVIEW

Seed dormancy and germination

In order that seeds may germinate certain conditions must be satisfied. These conditions are: moisture for rehydration, a suitable temperature, and sufficient available oxygen (54). Seeds which contain a viable embryo, but fail to germinate under conditions known to be optimum for the particular seed involved, are said to be dormant (10). When seeds are dormant following maturation on the plant, this dormancy is called primary dormancy. According to Crocker (10) dormancy generally results from the inhibition of one or more of the processes preceding or accompanying germination.

In many seeds the seed coat plays an important part in causing dormancy. The seed coat may prevent the entry of water (3) or oxygen (53), or may contain a growth-inhibiting substance (37).

Toole et al. (54) described work by Brown in which it was found that the inner membrane of the Cucurbita pepo seed coat was most permeable to gas when slightly less than completely saturated with water, and that in the dry condition the membrane was at least partly responsible for dormancy of this seed. Cormack (8) found that removal of the pericarp and seed coat from seeds of Tartary buckwheat (Fagopyrum tataricum) resulted in almost 100% germination within 1 to 3 days. He suggested that the seed coat, which is heavily cutinized, is almost impervious to water, and is chiefly responsible for dormancy of the seed.

In seeds of Alisma plantago the force exerted by the swelling seed is insufficient to rupture the seed coat. Germination is prevented by "mechanical restraint" (11).

Germination in seeds of a number of species is prevented by the presence of an inhibitor in some part of the fruit or seed structure. Evenari (17) lists a variety of compounds found by a number of workers to be responsible for seed dormancy. Barton (4) and Elliott (14), however, found that growth-inhibiting substances may also be present in aqueous extracts of non-dormant seeds of a number of cultivated species. Lehmann (29) reported the presence of a water-soluble growth inhibitor in the pericarp of fruits of Fagopyrum esculentum. Results of recent experiments with wild oats indicated that some water-soluble substance present in the hull could under suitable conditions diffuse into the seed, thus causing dormancy in otherwise non-dormant embryos (37).

Methods of overcoming seed dormancy are varied in nature, and generally depend upon the particular type of dormancy involved. In seeds of the majority of species dormancy may be overcome by a period of after-ripening, whether this be in dry storage at room temperature (9, 28, 52), or at low temperature under moist conditions (12).

Germination of seeds of many grasses has been improved by breaking, acid-treating, or removing certain seed coverings (13, 25, 54). Seed coats of "hard" legume seeds have been made permeable to water by soaking the seeds in absolute alcohol (3), freezing dry or wet seeds for varying lengths of time (33), heating seeds to temperatures ranging from 60° C. to 105° C. (43, 48), or by mechanical

scarification (3). Germination of freshly harvested seeds of wheat, oats, and barley has been improved by heating the seeds at 40° C. for 5 to 10 days, or by scarification with concentrated sulfuric acid (23).

Emparan and Tysdal (15) showed that seeds of guayule (Parthenicum argentatum) lost their dormancy completely after being exposed to light for 3 to 4 days, and subjected to the oxidative effect of a 0.75% solution of sodium hypochlorite. Treatment with potassium alpha-naphthaleneacetate had no significant effect on dormancy in seeds of several species of trees and shrubs (2).

In seeds of cereal crops Larson et al. (28) found wide varietal differences in length of dormancy period. Length of this period was increased by low storage temperature, and by immaturity of the seed.

The relationship between maturity and viability of seeds of a number of weed species was studied by Gill (21). He found that all open flowers of sow thistle (Sonchus arvensis) on drying produced viable seeds, while the same was not true for Canada thistle (Cirsium arvense) and dandelion (Taraxacum officinale). In several other species, seeds at the milk-ripe stage were shown to be viable, though in some cases a period of after-ripening was required before germination would take place.

Germination of weed seeds under laboratory conditions often presents difficulties, mainly because the conditions required for best germination of seeds of a given species are unknown. For testing germination of seeds of a number of cultivated species specific recommendations

are available (1). Weed seeds, like seeds of cultivated crops, may require widely different conditions for best germination, and some investigations have been carried out in order to determine these requirements (50).

Chepil (7) studied periodicity of germination of a large number of weed seeds in cultivated soil. Most of the species studied produced the greatest number of seedlings during the first year following fall seeding, with a smaller number, or none at all, emerging during subsequent years. Warrington (55) found that germination of seeds of a number of weed species in arable soil was inhibited if temperature fluctuation was slight, and light was wholly or partly excluded. Other workers concluded that alternating temperatures increased germination of seeds of some species, but had no effect on others (24, 34).

The effect of high temperatures on viability of wheat and barley seeds was investigated by Hutchinson et al. (26). Seeds initially containing 14% moisture showed delayed germination after treatment at 68° - 70° C., and were killed after 40 minutes exposure to 74° C. Kiesselbach (27) showed that, except for a small number of seeds with a high initial moisture content, seed corn was not injured by drying down to 5% moisture at 42° - 44° C.

A combination of high moisture content and exposure to high temperature prevented germination of all seeds studied by Siegel (46). Dry seeds were quite tolerant to high temperature treatments, with wheat, flax, and radish being some of the more resistant species. Air-dry wheat seeds showed little effect of exposure to 100° C. for 60 minutes.

Growth and development

Tartary buckwheat (Fagopyrum tataricum (L.) Gaertn.), a member of the family Polygonaceae, is described by Budd (5) as

"an annual weed from 2 to 3 feet in height, with roughly triangular leaves often as broad as long, growing from 1 to 4 inches long and wide. Flowers small and white and borne in bunches on the flowering stems, which arise from the junction of the leaf stalks and stems" (Figs. 1 and 2).

The growth habit of the plant is indeterminate, and that more so than in common buckwheat (32). In contrast to the latter species, which is self-sterile, Tartary buckwheat plants are self-fertile. Flowering begins five to six weeks after planting, gradually increases to a maximum, and then decreases. It may continue until stopped by frost in the fall. The first grains begin to ripen about three or four weeks after flowering starts, and ripening continues until frost (41).

The photoperiodic responses of Tartary buckwheat were investigated by Skok and Scully (47), who subjected plants of this species to photoperiods of varying duration during their entire growing period. Short photoperiods promoted floral development and fruiting as well as lateral shoot development, but depressed elongation of the main axis. Long photoperiods, on the other hand, favoured growth of the main axis and increase in total plant weight, but depressed lateral shoot growth, floral development and fruit production. These workers concluded that both vegetative and reproductive development were substantially regulated by photoperiodic mechanisms.

The fruit of Tartary buckwheat is an achene and is

"strongly protruding from the sepals, rather sharply 3-sided and edged near the tip, in the lower part (towards the sepals) wrinkled and notched on the edges, brownish or dark grey, rough and dull, 3/16 inch in length or somewhat longer" (18).

The external features of the seed are illustrated in Fig. 3. Fig. 4 shows in diagram form the internal structures of the seed of Tartary buckwheat in cross section. Chemical composition of the seed is presented in Table I.

Table I. Chemical composition of seeds of Tartary buckwheat
(Martin and Leonard (32)).

Total dry matter	89.6%
Protein	10.7%
Fat	2.4%
Fiber	15.2%
N-free extract	59.6%
Ash	1.7%

Some morphological changes taking place in the maturing seed are described by Cormack (8), who made microscopic examinations of a number of seeds at different stages of maturity. He paid special attention to the pericarp and seed coat, and found that

"in a green immature seed the seed coat consists of a single row of large cells whose walls give a positive test for cutin. The pericarp, on the other hand, is made up of three distinct layers: (1) an outer

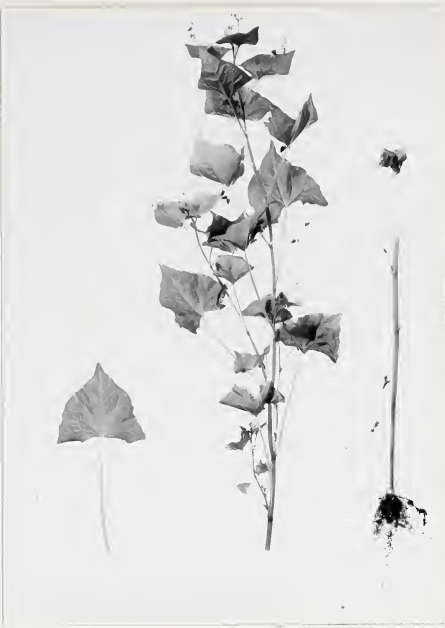


Fig. 1. Tartary buckwheat plant
($\frac{1}{4}$ x actual size)



Fig. 2. Branch with flowers,
immature seeds, and
mature seeds



Fig. 3. Mature seeds of Tartary
buckwheat
(4 x actual size)

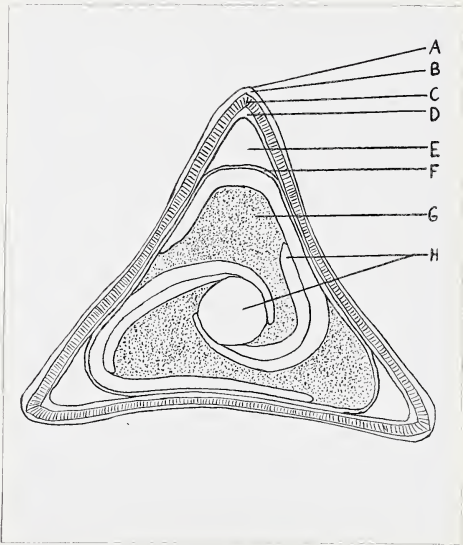


Fig. 4. Cross section of mature
Tartary buckwheat seed.
Redrawn from Cormack (8)

- A - cuticle)
- B - epidermis)
- C - sclerenchyma fibers) pericarp
- D - parenchyma)
- E - space between pericarp and seed
- F - seed coat
- G - endosperm
- H - embryo

layer consisting of a single row of extremely large and heavily cutinized epidermal cells, (2) a middle layer of sclerenchyma fibers, and (3) a wide inner layer of parenchymatous tissue."

The fiber walls thicken and become more lignified during maturation. The cells of the seed coat become compressed, and their walls heavily cutinized. In mature seeds the seed coat appeared almost completely impervious to water (8).

Probably because of the localized importance of Tartary buckwheat the plant has been given only passing mention in textbooks on either crop plants or weeds (32, 44). The species has been grown extensively as a cultivated crop in eastern Canada (18), and is still grown to some extent in the United States, though much less so than common buckwheat (Fagopyrum esculentum) (41). Because of its reported bitter taste and dark flour colour, seed of Tartary buckwheat is inferior to that of common buckwheat for flour making.

As a source of the substance rutin, which has been used in treatment of certain hemorrhagic conditions in humans, Tartary buckwheat has received some study. It was found that this species is 45 to 80 percent richer in rutin than is common buckwheat (Japanese variety) (8a).

Competition and control

Various surveys have indicated that annual losses attributed to weeds exceed those from any other group of agricultural pests (44). McRostie (31) estimated the total annual losses caused by weeds at almost two hundred million dollars in Canada, and at least two-thirds

of this amount was attributed to competition of weeds in growing crops. Results of crop loss studies carried out by Friesen (19) indicated an average reduction in crop yield of 15.9 percent, considering all crops and all locations included in the investigation. On the basis of the 1956 crop this meant a loss of over 43 million bushels of grain, through weed competition alone, to the Manitoba farmers.

Competition always occurs where two or more plants make demands for light, nutrients, or water in excess of the supply (56). Plant species may differ in their ability to compete with other plants for the supply available to them. In an effort to classify weeds and crop plants according to competitive ability, Pavlychenko and Harrington (40) studied the growth characteristics of a number of species. They concluded that success in competition depends on:

1. Readiness and uniformity in germination.
2. Development of a large assimilation surface at an early stage.
3. Possession of a large number of stomata.
4. A root system with a large mass of fiber close to the surface,
but with main roots penetrating deeply.

In order of decreasing competing ability cereal crops were classified as follows: (1) barley, (2) rye, (3) wheat, (4) oats, (5) flax. Of the weed species studied wild mustard and wild oats were the most serious competitors.

In order to reduce weed competition, especially during the early stages of crop growth, relatively heavy seeding, proper fertilization, and post-seeding cultivation have been recommended practices (22, 39).

A number of workers have carried out experiments designed to determine the amount of crop yield reduction caused by weed competition (6, 19, 22, 30, 49). Annual weeds present in soybeans during the entire growth period resulted in an average yield reduction of 10 per cent. The reduction in yield was roughly proportional to the amount of growth made by the weeds (49).

Mann and Barnes (30), studying competition between barley and certain other species, found that the plant which became established first was the strongest competitor. An infestation of Holcus mollis, established the previous year, could reduce the yield of a heavy-seeded barley stand by half, and could completely eliminate a thin stand of barley.

The reaction of wheat to the presence of wild mustard (Brassica arvensis) or its removal by various methods was investigated by Burrows and Olson (6). These workers, by spraying wheat plots infested with different numbers of wild mustard plants per square yard, attempted to find a minimum weed density at which spraying with 2,4-D could be considered justifiable. The experimental results indicated that spraying must be done early, i.e., when the weeds are small, if a grain yield increase is to be expected. The "critical" weed density was found to depend on the rate of seeding of wheat, and was higher for a higher rate of seeding.

Chemical control of weeds has been a recommended and almost universally accepted practice for a number of years now. However, in spite of extensive experimentation with numerous chemicals, still there remains a large number of weeds for which no practical or economical method of eradication or control has yet been found.

Tartary buckwheat has been the subject of a number of investigations concerned with chemical control. Table II provides a summary of the chemicals used in these experiments, the results of which have been reported in 41 abstracts in the research reports of the National Weed Committee, Western Section (Canada) (36) and the North Central Weed Control Conference (38) over the period 1951 - 1957. The great variety of results obtained under widely different conditions makes a summary of observations for each chemical impossible, and therefore only some of the outstanding conclusions will be mentioned. In the discussion the various herbicides will be referred to by using the abbreviations given in Table II. The terminology used, including the method of expressing rates of application, follows the recommendations of the Terminology Committee, Weed Society of America (45).

In general the "low-volatile" esters of 2,4-D were more effective in controlling Tartary buckwheat than were the more volatile esters. Ester formulations were practically always superior to amines and sodium- or potassium salts, though at higher rates the difference was often less marked. Formulations of MCPA, especially at the lower rates, were less effective than similar formulations of 2,4-D. Soil sterilants such as monuron, though sometimes resulting in good control, did not appear to have much practical value in controlling Tartary buckwheat except perhaps where small amounts of them were used in a mixture with, for example, 2,4-D. Neburon, a more recently developed chemical, has shown promising results, though for practical purposes the cost is still prohibitive.

Table II. Summary of chemicals used in experiments on control of Tartary buckwheat, as reported in abstract form in NCWCC and NWCWS research reports from 1951 to 1957.

Chemical	Range of rates	Number of experiments
2,4-dichlorophenoxyacetic acid (2,4-D):		
- ethyl ester	3 - 16 oz./A.	7
- isopropyl ester	4 - 8 oz./A.	1
- butyl ester	4 - 16 oz./A.	4
- butoxyethanol ester (IV)	4 - 16 oz./A.	10
- propylene glycol butyl ether ester	4 - 12 oz./A.	2
- alkanolamine	4 - 16 oz./A.	2
- amine	4 - 16 oz./A.	4
2-methyl-4-chlorophenoxyacetic acid (MCPA):		
- butyl ester	4 - 8 oz./A.	2
- butoxyethanol ester	4 - 16 oz./A.	1
- amine	4 - 16 oz./A.	4
- sodium salt	8 - 16 oz./A.	1
- potassium salt	6 oz./A.	1
4-chlorophenoxyacetic acid (4-CPA):		
- butoxyethanol ester	4 - 16 oz./A.	2
- amine	4 - 16 oz./A.	1
3,4-dichlorophenoxyacetic acid (3,4-DA) -		
butoxyethanol ester	4 - 16 oz./A.	1
3-amino-1,2,4-triazole (ATA)	4 - 16 oz./A.	1
dinitro (Dow Selective)	1 - 3 qt./A.	2
sodium cyanamide	40-100 lb./A.	1
potassium cyanate (KOCN)	8 - 12 lb./A.	1
sodium trichloroacetate (Na-TCA)	10- 50 lb./A.	1
3-(p-chlorophenyl)-1,1-dimethylurea (Monuron)	1 - 10 lb./A.	2
isopropyl N-(3-chlorophenyl) carbamate (CIPC)	6 - 18 lb./A.	1
2,4-dichlorophenoxyethylsulfate (Crag No. 1)	1- 2.5 lb./A.	1
polychlorobenzoic acid	0.5- 1 lb./A.	1
3-(3,4-dichlorophenyl)-1-methyl-1-n- butylurea (neburon)	0.5-10.8 lb./A.	3

Present recommendations for chemical control of Tartary buck-
wheat state:

"Control or suppression of this weed in crops of wheat and barley usually can be achieved by treatment with 6 to 8 oz. 2,4-D ester per acre as soon as the weed population and crop growth permit. Low volatile forms of 2,4-D tested at comparable rates result in a somewhat higher degree of control. MCPA ester at 8 - 12 oz./A. will give a reasonable measure of control, especially at the upper end of the rate range. The esters of MCPA should be considered for use in oats and flax and where very early sprayings of wheat and barley are deemed advisable. Better control will result when the treatments are made at an early growth stage of the weed, preferably not later than the first or second true leaf stage. The formulation and rates recommended will reduce but not completely prevent seed setting of the buckwheat." (35).

EXPERIMENTAL

I. Seed Dormancy

1. Materials and methods

At the time the work was initiated, a quantity of Tartary buckwheat seed was obtained from a seed cleaning plant in Vegreville, Alberta, through courtesy of the District Agriculturist. Seed used in germination tests in the study of seed dormancy was collected in the field or in the greenhouse from plants grown from the initially obtained seed or from seed harvested at the end of the 1956 growing season. The experimental results did not indicate any differences in dormancy as being related to the source of the seed. Nevertheless, the source will be indicated wherever it appears necessary for clarity.

The indeterminate growth habit of the plant made it impossible to obtain a quantity of seed completely uniform in degree of maturity. Mature seeds present on a plant at a certain stage may have been mature for some time, and consequently may have gone through a part of their after-ripening period prior to being collected. Therefore, where mature seeds were used, an attempt was made to collect seeds at a stage which might be termed "newly mature."

Unless stated otherwise, all germination tests were carried out using duplicate samples of 50 seeds each, between folded, moist paper towels, in a dark germinating cabinet in which a temperature of 20° C. was maintained. In almost all cases the seeds were treated with dry Orthocide prior to the germination test in order to prevent

fungus growth. Seeds were considered germinated when the radicle had broken through the pericarp and had reached a length of at least two millimeters. Germinated seeds were counted and removed from the germinator at three and seven days after the beginning of the test. In most cases only the seven-day counts are reported.

Low and high temperature treatments consisted of placing the seed in a refrigerator, controlled-temperature room, or electric oven, in each of which the temperature was maintained within 1° C. of the specified temperature.

For convenience in handling, the samples of 50 seeds each were placed in 2-coin paper envelopes for treatments of relatively short duration (up to 72 hours). For treatments of longer duration, in which periodic germination tests were carried out, a sufficient quantity of seed was stored in a waxed-paper container (capacity 135 ml.) under the conditions specified.

The progress of water imbibition in dormant and non-dormant seeds was investigated by soaking duplicate 100- or 200-seed samples in distilled water, and determining the increase in weight as a result of water uptake after different intervals. In order to get reproducible results, seeds were taken from the water, the excess water was removed by suction, and the seeds were allowed to dry on paper towels for fifteen minutes, following which they were weighed.

For moisture determinations duplicate samples of approximately 100 seeds each were ground in a Wiley mill through a 20-mesh screen,

weighed, and dried at 105° C. for one hour, following which they were weighed again, and the moisture content was calculated. Where the moisture content of soaked seeds was determined, whole seeds were used, and the samples were dried for 16 to 20 hours at 105° C. All moisture contents were calculated on the basis of the oven-dry weight of the sample.

To obtain seeds with different moisture contents, seeds were soaked in water and redried, or small volumes of water were added to seed samples whose weight and initial moisture content were known, to bring them up to approximately the desired moisture level. Calculated levels were confirmed by actual moisture determinations.

Extracts for inhibitor tests were obtained by the following methods:

1. Soaking whole seeds in distilled water for 24 hours.
2. Shaking ground seeds in distilled water overnight, and filtering the resulting suspension.
3. Refluxing ground seeds with 95% alcohol for eight hours, and after evaporation dissolving the residue in distilled water.
4. Expressing the juice of water-soaked seeds in a Carver hydraulic press at 15,000 p.s.i.

An oxygen-free atmosphere for seed storage was obtained by placing the seeds under a bell jar, which was then evacuated, and had nitrogen run through it for approximately five minutes. An atmosphere of pure oxygen was obtained in a similar manner.

2. Experiments involving pericarp and seed coat

It had been found earlier by Cormack (8) that removal of the pericarp and seed coat from seeds which previously failed to germinate resulted in almost 100 percent germination within one to three days. If the seed coat is impermeable to water, and thus prevents germination, as suggested by Cormack, pricking a hole through both pericarp and seed coat, or cutting a slice approximately $\frac{1}{2}$ mm. thick off the base of the seed, should allow sufficient water to enter the seed, and thus to overcome the cause of dormancy. Table III shows the results of two experiments in which the above treatments were included. The seeds were soaked in water prior to treatment in order to facilitate dissection.

Table III. Percentage germination of dormant and non-dormant seeds of Tartary buckwheat from which the pericarp and seed coat were partly or entirely removed.

Treatment	% germination		
	Fresh seeds	Seeds in refrigerator for six weeks	Non-dormant seeds
None - seeds entire	0 (0)*	4	86
Pericarp removed	0 (3)	4	100
Pericarp and seed coat removed	10 (13)	20	-
Seeds pin-pricked	0 (1)	6	90
$\frac{1}{2}$ mm. slice cut from base of seed	0 (5)	4	100
Number of seeds per treatment	4 x 25	25	50

* % germination after 14 days

In two other experiments involving small numbers of seeds which had failed to sprout in the germinator, removal of both pericarp and seed coat resulted in up to 50 percent germination. Non-dormant seeds did not suffer any serious injury from similar treatments.

To investigate the permeability of the seed-surrounding structures to water, several experiments were carried out, in which the amount of water taken up by imbibition was determined as a percentage of the initial air-dry weight of the seed sample. The results of two experiments are shown in Table IV. Newly collected mature seeds were stored dry at room temperature for some time in order to get comparable initial moisture contents in dormant and non-dormant seed samples.

Table IV. Percentage increase in weight of dormant and non-dormant seeds of Tartary buckwheat after soaking in water.

Hours soaked	% increase in weight			
	Experiment I		Experiment II	
	Dormant*	Non-dormant	Dormant**	Non-dormant
$\frac{1}{2}$	19.6	31.8	26.3	28.9
1	22.0	33.6	28.6	31.1
2	26.6	38.1	32.1	35.5
4	32.0	40.2	37.6	39.9
8	37.1	42.8	42.7	41.0
24	47.1	48.0	48.4	46.9
48	49.8	50.9	49.6	49.1
120	53.4	54.0	-	-
Initial moisture content (%)	9.5	8.3	11.0	11.4

* Seed stored dry at room temperature for 12 days after collecting
 ** Seed stored dry at room temperature for 5 days after collecting

The first part of the report deals with the general situation of the country, and the second part with the specific details of the project. The first part is divided into two sections: the first section deals with the general situation of the country, and the second section deals with the specific details of the project. The second part is divided into two sections: the first section deals with the general situation of the country, and the second section deals with the specific details of the project.

Table 1: Summary of the project results				
Year	Project A	Project B	Project C	Total
1990	100	200	300	600
1991	120	220	320	660
1992	140	240	340	720
1993	160	260	360	780
1994	180	280	380	840
1995	200	300	400	900
1996	220	320	420	960
1997	240	340	440	1020
1998	260	360	460	1080
1999	280	380	480	1140
2000	300	400	500	1200
2001	320	420	520	1260
2002	340	440	540	1320
2003	360	460	560	1380
2004	380	480	580	1440
2005	400	500	600	1500
2006	420	520	620	1560
2007	440	540	640	1620
2008	460	560	660	1680
2009	480	580	680	1740
2010	500	600	700	1800
2011	520	620	720	1860
2012	540	640	740	1920
2013	560	660	760	1980
2014	580	680	780	2040
2015	600	700	800	2100
2016	620	720	820	2160
2017	640	740	840	2220
2018	660	760	860	2280
2019	680	780	880	2340
2020	700	800	900	2400
2021	720	820	920	2460
2022	740	840	940	2520
2023	760	860	960	2580
2024	780	880	980	2640
2025	800	900	1000	2700
2026	820	920	1020	2760
2027	840	940	1040	2820
2028	860	960	1060	2880
2029	880	980	1080	2940
2030	900	1000	1100	3000

Lehmann (29) reported the presence of a water-soluble growth-inhibiting substance in the pericarp of seeds of Fagopyrum esculentum. In order to determine whether or not a similar substance was present in seeds of Tartary buckwheat, several experiments were carried out in which seeds of this species were germinated in extracts of both dormant and non-dormant seeds. In no case did the results of these experiments indicate the presence of a growth-inhibiting substance in seeds of Tartary buckwheat.

3. Chemical treatments

Treatment of seeds with various chemicals, resulting in scarification or some physiological effect, has been shown successful in overcoming dormancy in a number of species (3, 13, 15, 25).

Seeds of Tartary buckwheat were subjected to a number of chemical treatments in order to study the effects of these treatments on dormancy. The results of some of these experiments are presented in Table V.

Dormant or partially dormant seeds responded erratically to treatment with gibberellic acid or the potassium salt of this acid. Table VI shows the results of some representative experiments.

Table V. Percentage germination of Tartary buckwheat seeds subjected to various chemical treatments.

Chemical	Time of treatment	% germination	
		Non-dormant seeds	Dormant seeds
95% H ₂ SO ₄	0 - 10 min.	100	1
95% H ₂ SO ₄	20 min.	84	1
95% alcohol	control	88	30
95% alcohol	2½ min.	68	14
95% alcohol	5 - 20 min.	54	5
80% alcohol	1 hour	0	0
1% KNO ₃	0 - 4 hours	96	6
2% KNO ₃	0 - 4 hours	86	6
Distilled water	2 hours	91	15
0.5% Ca(OCl) ₂	2 hours	83	17
2% Ca(OCl) ₂	2 hours	47	18

Table VI. Percentage germination of dormant Tartary buckwheat seeds following soaking in solutions of gibberellin for 24 hours.

Concentrations of gibberellin (acid equiv.)	Fresh seeds		Partially dormant seeds
	Intact seeds	Cut seeds*	
0	0	0	5
100 ppm.	0	2	3
500 ppm.	0	0	5
1000 ppm.	0	0	19
2000 ppm.	0	-	-

* A slice approximately ½ mm. thick removed from the base of the seed to facilitate entry of the solution.

4. Germination following field planting or storage
under various conditions

Part of the mature and immature seed collected periodically from plants growing in field plots during 1956 and 1957 was planted in the field immediately after being collected, while the remainder was stored under various conditions in the laboratory. The experimental results indicated no difference in behaviour which could be related to planting or collection time, and therefore no reference will be made to these factors.

Field plantings of freshly collected seeds did not yield any seedlings during the same season. Of the fresh seeds planted during August and September 1956 ten to twenty percent produced seedlings the following spring. Disturbance of the plots by surveyors caused these data to be somewhat unreliable. Observations on emergence from 1957 plantings will be made in the spring of 1958.

Seed of the 1956 crop was stored dry at 2° - 3° C. in a refrigerator, at room temperature on a laboratory bench, and at 40° C. in an electric oven. Figs. 5, 6, and 7 show the germination results of representative samples of mature and immature seed stored under these conditions. An additional treatment consisting of one or thirty days' exposure to -20° C. in most cases did not affect germination, but where seeds had a relatively high moisture content at the time of treatment, their germination was decreased sharply. Seeds collected during 1957, and stored dry at room temperature or in the refrigerator for varying periods, yielded essentially the same germination results as did the 1956 seeds.

Fig. 5. Germination of fresh Tartary buckwheat seeds following dry storage in the refrigerator (2° - 3° C.)

Fig. 6. Germination of fresh Tartary buckwheat seeds following dry storage at room temperature

Fig. 7. Germination of fresh Tartary buckwheat seeds following dry storage in an electric oven (40° C.)

Fig. 5

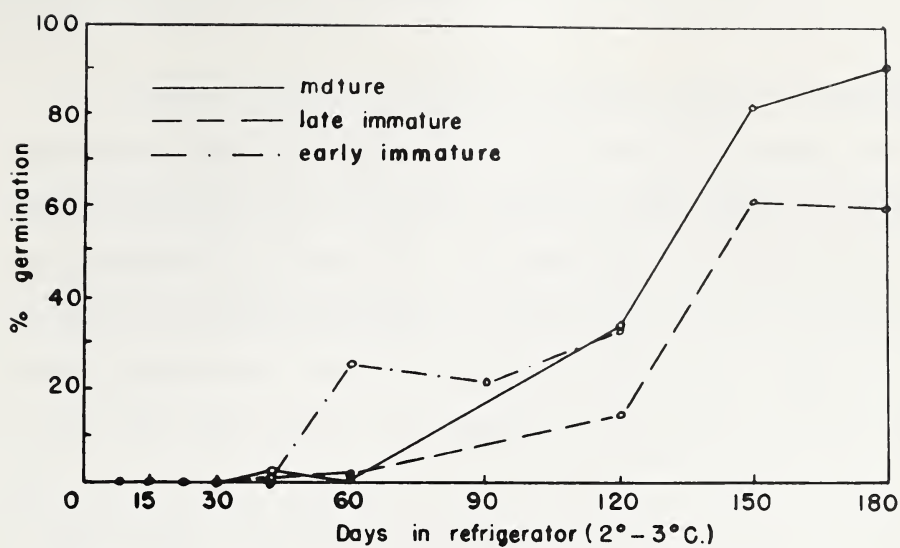


Fig. 6

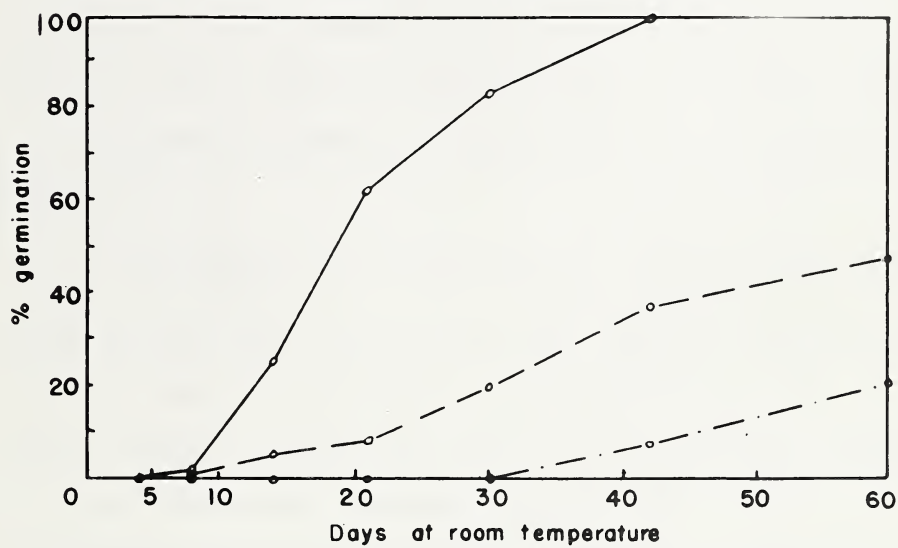
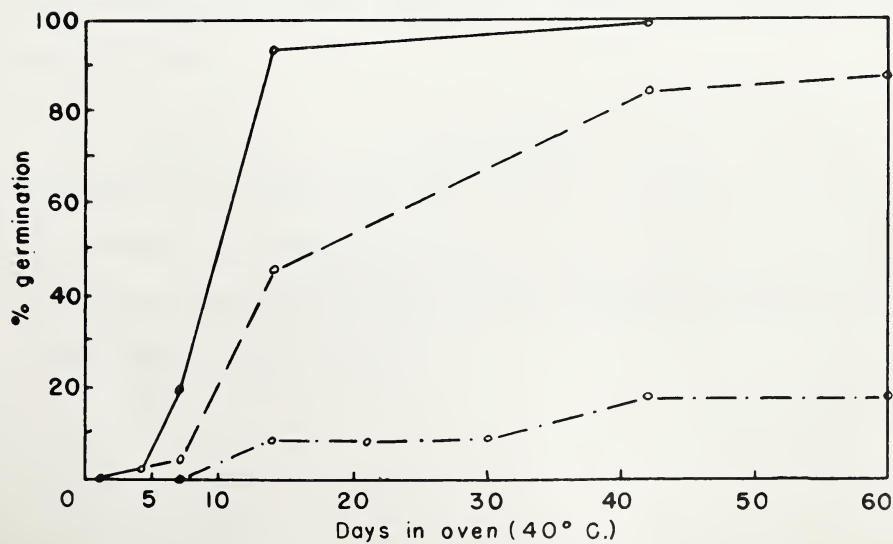


Fig. 7



Seeds of a number of species have been shown to after-ripen most quickly when stored under moist conditions at low temperature (stratification)(12, 54). Tartary buckwheat seeds stored for periods up to six months at 5° and 10° C. in waxed-paper containers filled with moist vermiculite appeared to have the same degree of dormancy as freshly picked seeds, and had to be stored dry at room temperature for at least four weeks before the majority of the seeds would germinate. Seeds kept saturated with moisture at room temperature similarly failed to after-ripen. In a later experiment dormant seeds were stored for four months in a refrigerator (2° - 3° C.) under the same moisture conditions as above. When the seeds were taken from storage and placed in the germinator, 80 percent of them germinated over a period of 17 days.

Subjecting mature dormant seeds to alternate wetting and drying in petri dishes did not break their dormancy. When seeds were planted in pots, and allowed to dry out for two weeks, subsequent wetting resulted in germination of 68 percent of the seeds (average of six pots). Alternating temperature treatments (20° to 30° C. or -20° C. to room temperature) were ineffective in overcoming dormancy of Tartary buckwheat seeds.

Seeds stored in an oxygen atmosphere under a bell jar did not after-ripen more quickly, and seeds stored in nitrogen lost their dormancy somewhat more slowly than seeds in air. The difference was not sufficiently great to establish that the presence of oxygen is essential to the after-ripening process.

In all experiments described so far the seeds were kept in containers in which at least a certain amount of gas exchange was possible. When dormant seeds, immediately or soon after being collected, were placed in glass tubes closed with rubber stoppers, these seeds lost their dormancy much more quickly than did similar seeds kept in open containers. Germination results of two experiments are shown in Table VII.

Table VII. Percentage germination of Tartary buckwheat seeds after storage in open or closed containers at room temperature.

Weeks stored	% germination					
	Experiment I		Experiment II			
	Open	Closed	Open	Closed	Closed	
0	2	-	0	-	-	
1	6	32	1	2	2	
2	8	45	0	41	1	
3	19	99	11	100	2	
4	50	100	-	-	-	
5	72	100	-	-	-	
Initial % moisture	-		21.9%	app. 30%		

5. Low- and high-temperature treatments

From the germination results obtained after storing seeds under different conditions it was evident that seed dormancy was overcome more quickly during dry storage at a relatively high temperature (40° C.) than at a low temperature (2° - 3° C.). Further experimentation

indicated that relatively short exposures to much higher temperatures were very effective in overcoming dormancy.

In a number of preliminary experiments it was found that non-dormant seeds, containing nine to ten percent moisture in an air-dry condition, were not noticeably affected by exposures of up to 24 hours to temperatures ranging from -20° to 90° C. Exposure of these seeds to 100° C. for as little as five minutes seriously reduced the percentage germination. Seeds soaked in water for two hours were killed by freezing at -20° C. Similarly pretreated seeds were not affected by drying at 50° C. or 60° C. Drying at 80° C. resulted in considerable injury to seeds with an initial moisture content greater than approximately 20 percent. If soaked seeds were placed in stoppered glass vials, they could withstand at least four hours at 50° C. without suffering injury, but more than five minutes at 60° C. reduced germination considerably, and thirty minutes' exposure to this temperature resulted in death of all seeds.

The moisture content of freshly collected seeds varied considerably, and ranged approximately from 10 to 20 percent, depending on the relative humidity of the atmosphere, and on the length of time since actual maturation of the seeds on the plant. Drying of the seeds at room temperature proceeded quite rapidly; in one experiment the moisture content fell from an initial 22 percent to 10 percent in twelve days.

The first effects of high-temperature treatment on dormant seeds were observed when mature seeds, which had partly lost their dormancy during four months' storage in the refrigerator, were dried at

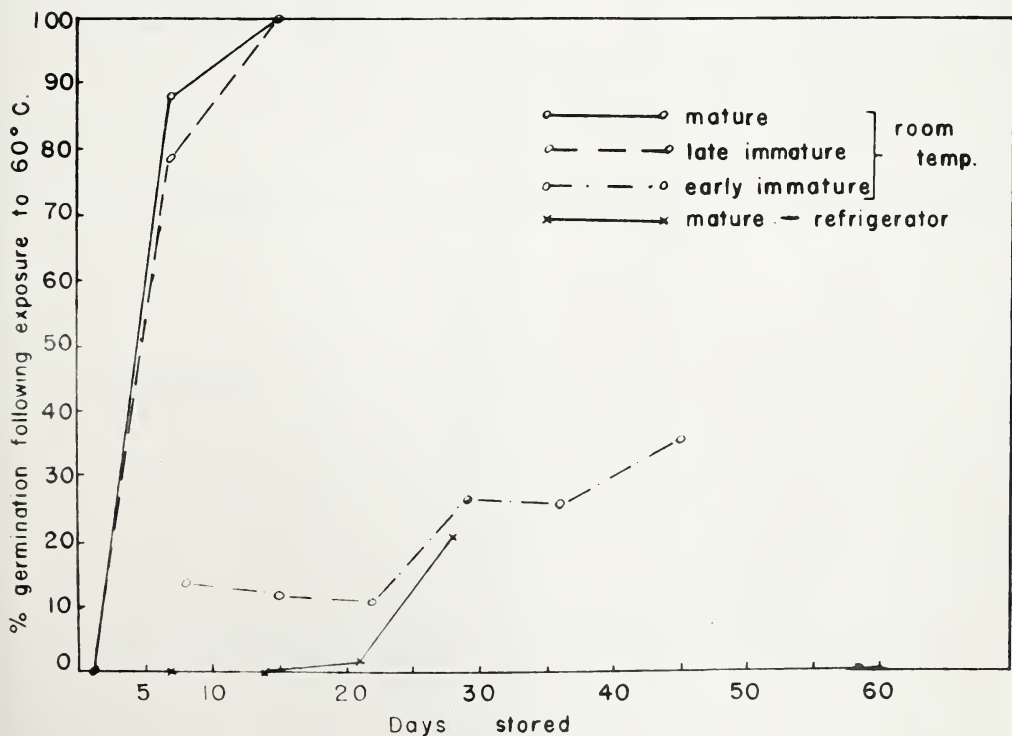
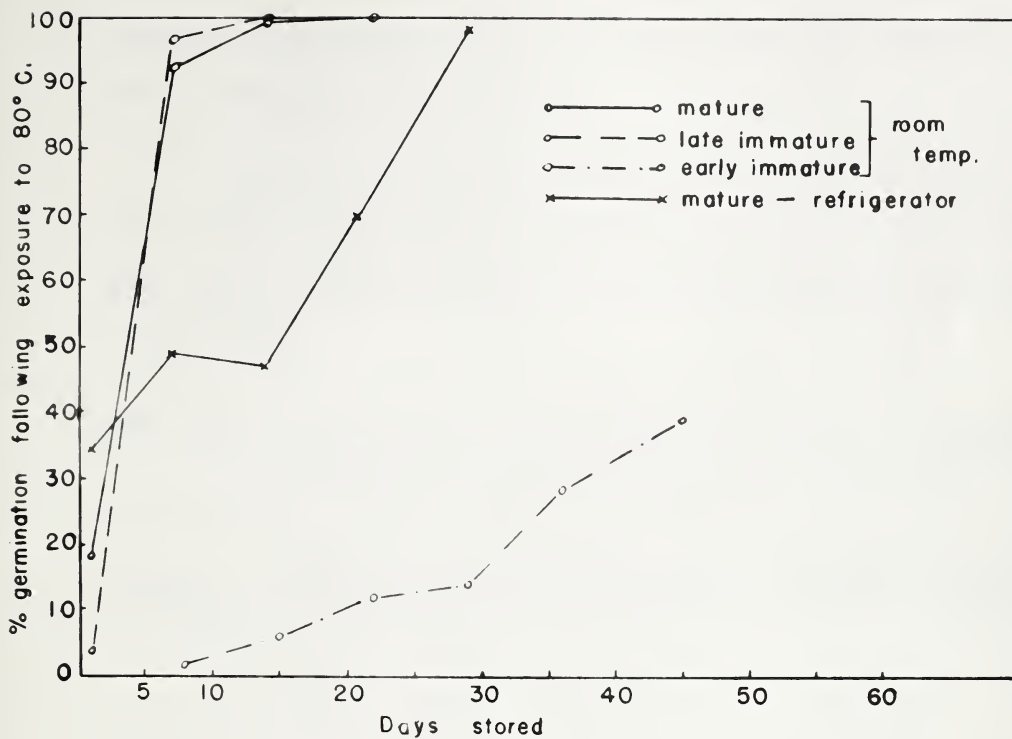
80° C. for 1 to 24 hours. From 92 to 100 percent of the seeds germinated after treatment for at least two hours. Further investigation showed that similar results could be obtained by drying the seeds at 70° or 90° C., though in some cases the latter temperature proved to be too high, and treatment resulted in delayed germination and stunted seedlings. At 70° C. a longer exposure was required than at 80° C. to obtain comparable germination results.

Fully dormant seeds, unable to germinate after being stored in the refrigerator for varying periods following collection, showed essentially the same response to high temperature as that noted above. Results indicated that the shorter the period of storage at room temperature, the longer the exposure required at high temperature to attain comparable germination results of the samples. Freshly collected mature seeds did not lose their dormancy completely after 24 hours at 80° C., but required 48 or sometimes 72 hours at that temperature to achieve this result. That the seeds were not killed by this drying treatment was shown by storing the non-germinated seeds dry at room temperature for four to six weeks, and then observing growth after placing them in the germinator again.

To determine the relationship between length of preliminary storage and the effect of high temperature treatment a quantity of seed was collected, and part of it stored dry at room temperature, while the remainder was kept in the refrigerator. Periodically samples of this seed were exposed to 80° C. for 24 hours, and their germination percentage determined. Results obtained with both mature and immature seed are illustrated in Fig. 8. Germination results with untreated

Fig. 8. Germination of fresh Tartary buckwheat seeds following dry storage in the refrigerator or at room temperature, and exposure to 80° C. for 24 hours

Fig. 9. Germination of fresh Tartary buckwheat seeds following dry storage in the refrigerator or at room temperature, and exposure to 60° C. for 24 hours in a stoppered glass vial



samples are not included here, since they followed very closely the curves presented in Figs. 5 and 6.

Results of an experiment similar to the previous one are shown in Table VIII. In this experiment the moisture content of the seeds before and after treatment, as well as the percentage germination was determined.

Table VIII. Moisture content and percentage germination of Tartary buckwheat seeds dried at 80° C. for 24 hours following storage at room temperature or in the refrigerator.

Storage	Weeks stored	No treatment		Dried 24 hours at 80° C.	
		% moisture	% germination	% moisture	% germination
Room temperature	0	17.6	0	1.8	64
	1	14.1	4	1.8	98
	2	12.0	51	2.4	100
	3	9.9	59	1.8	100
	4	9.8	95	1.8	100
	5	8.4	100	1.8	100
Refrigerator	0	17.7	0	1.8	36
	1	17.0	0	1.9	54
	2	16.0	1	2.4	61
	3	15.2	0	1.7	81
	4	14.3	0	1.8	99
	5	12.3	3	1.8	99

and (b) the fact that the Commission has not yet received any information from the Government of the United Kingdom regarding the results of its investigation into the matter.

The Commission is also aware of the fact that the Government of the United Kingdom has not yet received any information from the Government of the United Kingdom regarding the results of its investigation into the matter.

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100	1	1	100	1
100	1	1	100	1
100	1	1	100	1
100	1	1	100	1
100	1	1	100	1
100	1	1	100	1
100	1	1	100	1

The Commission is also aware of the fact that the Government of the United Kingdom has not yet received any information from the Government of the United Kingdom regarding the results of its investigation into the matter.

100	1	1	100	1
100	1	1	100	1
100	1	1	100	1
100	1	1	100	1
100	1	1	100	1
100	1	1	100	1
100	1	1	100	1

The Commission is also aware of the fact that the Government of the United Kingdom has not yet received any information from the Government of the United Kingdom regarding the results of its investigation into the matter.

The effect of heating to 60° C. in a closed container on dormancy of Tartary buckwheat seeds was first observed in an experiment of which the results are presented in Table IX. Heating seeds in coin envelopes had essentially the same effect here as in previous experiments. Seeds placed in rubber-stoppered glass vials were all killed by heating to 80° C., and almost all were killed by exposure to 70° C. Heating to 60° C., however, resulted in 100 percent germination.

Table IX. Moisture content and percentage germination of Tartary buckwheat seeds following heating to different temperatures in open or closed containers.

Container	Hours heated	80° C.		70° C.		60° C.	
		% moisture	% germination	% moisture	% germination	% moisture	% germination
-	Check	-	2	-	8	-	9
Coin envelope	24	-	-	-	53	-	42
	48	1.6	90	2.4	91	-	75
	72	-	100	-	99	3.3	96
Stoppered glass vial	24	-	-	-	17	-	100
	48	8.4	0	8.4	2	-	100
	72	-	0	-	0	9.1	100

This treatment (heating to 60° C. for 24 hours in a closed container) was also applied to samples of seed taken from the same sources as those discussed on page 29 (room temperature and refrigerator; results in Fig. 8). The results of this treatment at the lower temperature are illustrated in Fig. 9. Because the two treatments (heating at 80° C. and at 60° C.) were part of the same experiment, the results in Figs. 8 and 9 may be compared directly.

Table X shows the results of further investigation of the relative importance of temperature and moisture content in the process of after-ripening. In order to dry the seeds without heating them, they were placed in a desiccator containing a dish with concentrated sulfuric acid which had previously been boiled for four hours. Following the treatment both the moisture content and the percentage germination of the seeds were determined.

Table X. Moisture content and percentage germination of Tartary buckwheat seeds after various heating and drying treatments (seed collected 3 days before the start of the experiment).

Treatment	Time	% moisture	% germination	Total % * germination
No treatment	-	9.37	2	99
Dry storage	14 days	8.38	15	100
at room	21 days	8.56	20	98
temperature	28 days	8.83	81	83
Storage in	7 days	4.21	4	100
desiccator with	14 days	2.98	7	92
H ₂ SO ₄ at room	21 days	2.44	11	96
temperature	28 days	2.14	9	11
Storage in	7 days	7.37	2	100
desiccator with	14 days	6.16	1	100
H ₂ SO ₄ in the	21 days	5.41	1	100
refrigerator	28 days	5.09	1	9
Heating	8 hours	3.62	14	100
to	24 hours	2.66	30	100
70° C.	48 hours	2.33	77	100
	72 hours	2.32	90	100
Heating	8 hours	3.08	11	100
to	24 hours	1.92	40	100
80° C.	48 hours	1.38	86	100
	72 hours	0.99	96	99

* Total percentage germination after storing non-germinated seeds of the first test for two months.

6. Discussion and conclusions

Dormancy in seeds of Tartary buckwheat does not seem to be caused by any one single factor such as the suggested impermeability of the seed coat to water (8). In the experiments carried out the seed coat did not prevent the entry of water into dormant seeds. Complete removal of both pericarp and seed coat resulted in an increase in germination, but partial removal of these structures by dissection or by scarification with concentrated sulfuric acid did not overcome dormancy. There was no evidence of the presence of a growth-inhibiting substance or of a "mechanical restraint" effect of the seed coat or pericarp.

Treatment with various chemicals including potassium nitrate and gibberellin had no effect on dormancy of fresh seeds. Seeds which had after-ripened for some time, showed an increase in germination following treatment with gibberellin.

Stratification at 5° or 10° C. did not overcome dormancy. A lower temperature indicated more promising results, but further investigation is required before a definite conclusion can be drawn. Under field conditions immature or newly mature seeds failed to send up shoots during the same season if they were planted immediately after being collected. The following spring a small percentage (10 - 20 percent) of the seeds germinated, and produced seedlings. Presumably the remainder of the seeds remained dormant in the soil. It will certainly be fruitful to investigate this aspect of the problem more thoroughly, though the project must of necessity be carried out over a number of years.

Dormancy of freshly harvested seeds could be overcome under different conditions of dry storage, but the after-ripening process took place much more quickly at a relatively high temperature than at a low temperature (Figs. 5, 6, and 7). Mature seeds which required five to six months to after-ripen at 2° - 3° C., lost their dormancy in two weeks at 40° C. Immature seeds required a considerably longer period to after-ripen under similar conditions, and then did not attain the same percentage germination as did the mature seeds.

Temperature apparently played an important part in determining the rate of after-ripening. At low temperature (2° - 3° C.) the process took place very slowly, while the rate was increased by higher temperature to a maximum at approximately 80° C. The favourable effect of high temperature treatment in overcoming seed dormancy appeared to be related to the length of storage following collection, and to the storage conditions. Freshly collected mature seeds did not lose their dormancy completely after 24 hours at 80° C., but required up to 48 or 72 hours exposure to achieve that result. Mature seed stored at room temperature for one week germinated 92 - 97 percent following a standard treatment of drying at 80° C. for 24 hours, while similar seeds kept in the refrigerator required four weeks of storage before a comparable response was obtained (Fig. 8 and Table VIII). Early immature seeds did not respond to the treatment to the same extent as did more mature seeds.

The effects of a high-temperature treatment are made up of two factors, viz., heating and drying. Seeds placed in rubber-stoppered glass vials could not lose any moisture, and when seeds under these

conditions were heated to 60° C. for 24 hours, the effect on dormancy was found to be similar to that of drying at 80° C. for 24 hours, providing the initial moisture content in the closed vials was low enough to prevent injury (Fig. 9). Seeds kept in the refrigerator did not show any appreciable germination following the 60° C. treatment until they had been stored for four weeks, probably because of the low rate of drying in the refrigerator, and the subsequent injury to the relatively moist seeds as a result of heating in a closed container.

When dormant seeds were dried over concentrated sulfuric acid at room temperature or in the refrigerator (drying the seeds without heating them), after-ripening took place very slowly (Table X).

After-ripening of the seeds in an open container at room temperature or in the refrigerator was accompanied by drying out of the seeds (Table VIII). There was, however, no direct relationship between the moisture content and the percentage germination of the seeds after a given period of storage. Drying the seeds at 80° C. for 24 hours following storage reduced the moisture content to approximately 1.8 percent in most cases, but the seeds stored at the higher temperature responded to the treatment after a much shorter period of storage.

For seeds kept at room temperature the moisture content seemed to play an important part in determining the rate of after-ripening. Seeds in closed containers lost their dormancy more quickly than did those in open containers, possibly because the initial moisture content of the seeds in the closed containers was maintained throughout the course of the experiment, while the seeds in the open containers dried

out, and their moisture content fell below the optimum level for after-ripening. The optimum moisture level appeared to lie in the range of 15 - 20 percent.

The after-ripening process was affected much more strongly by temperature than by moisture content. There was an inverse relationship between temperature and optimum moisture content, i.e., for after-ripening at a given temperature there appeared to be an optimum moisture content which decreased with increasing temperature. At the higher temperatures this optimum value depended largely on the possible injury to the seed, while at the lower temperatures it was determined more directly by the actual after-ripening process.

II. Growth and Development

1. Materials and methods

Seed used in the experiments discussed was obtained from the source referred to in the previous section.

To determine the extent and progress of germination at different temperatures, triplicate 50-seed samples were placed on moist filter paper in petri dishes, and also planted $\frac{1}{2}$ " deep in pots filled with soil. Seeds were considered germinated when the radicle had broken through the pericarp, and had reached a length of at least two millimeters. Seedlings were considered emerged when the cotyledonary leaves appeared above the surface. The different temperature conditions were obtained in a room in which the temperature could be maintained within 1° C. of that specified. The same facilities were also used to determine the rate of elongation of germinating seedlings at different temperatures.

The relationship between depth of planting and emergence was investigated by planting seeds at different depths in the field or in pots with soil in the greenhouse, and observing the emergence of seedlings.

During almost the entire growing season in 1957 duplicate 100-seed samples were planted in the field at two-week intervals, and a record was kept of the emergence of seedlings in order to determine if there was any periodicity in germination, or any time during which seeds would not germinate and produce seedlings.

In order to investigate the progress of flowering and seed production quadruplicate plots of 10' 6" x 20' (1956) or 10' 6" x 15' (1957) were laid out, and Tartary buckwheat was seeded with a V-belt seeder in rows spaced 1' 6". One set of four plots was seeded on each of three dates in both years. Seeds in the two center rows were counted (250 seeds per 20 feet); these rows were used for emergence counts and for determinations of seed and straw yield in the fall.

To determine the progress of seed maturation field plots were seeded to Tartary buckwheat on three different dates in 1957. When seed production began, three plants were selected at random from each plot once a week, and all the seeds removed. The total number of seeds and the percentage mature seeds were then recorded.

The effect of spraying with 2,4-D on flowering, seed production, and seed viability was studied in an experiment in which quadruplicate 7' 6" x 10' plots were seeded to Tartary buckwheat in rows spaced 1' 6". The plants were sprayed with low volatile 2,4-D (Weedone LV4), using 40 gal./A. of solution. At harvest time the borders were trimmed, and the remainder of the plot harvested for determinations of yield and any abnormalities present in the seed.

2. Germination temperature

In the process of seed germination temperature is an important, and often determining factor. The range of temperatures within which seeds are able to germinate may vary considerably between species. The results of germination of Tartary buckwheat seeds, both in petri dishes and in pots with soil, at different temperatures, are illustrated in Fig. 10.

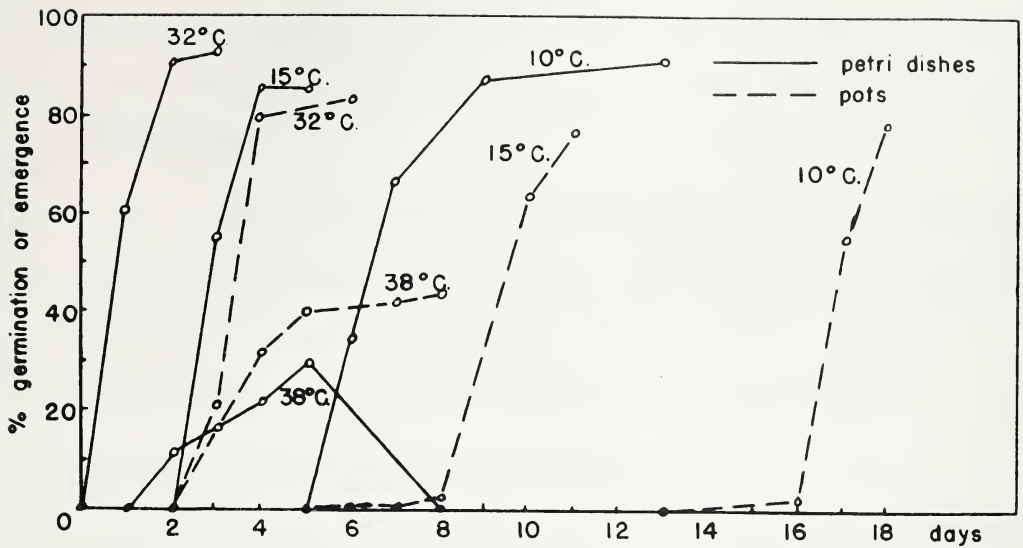


Fig. 10. Rate of germination and emergence of Tartary buckwheat at different temperatures

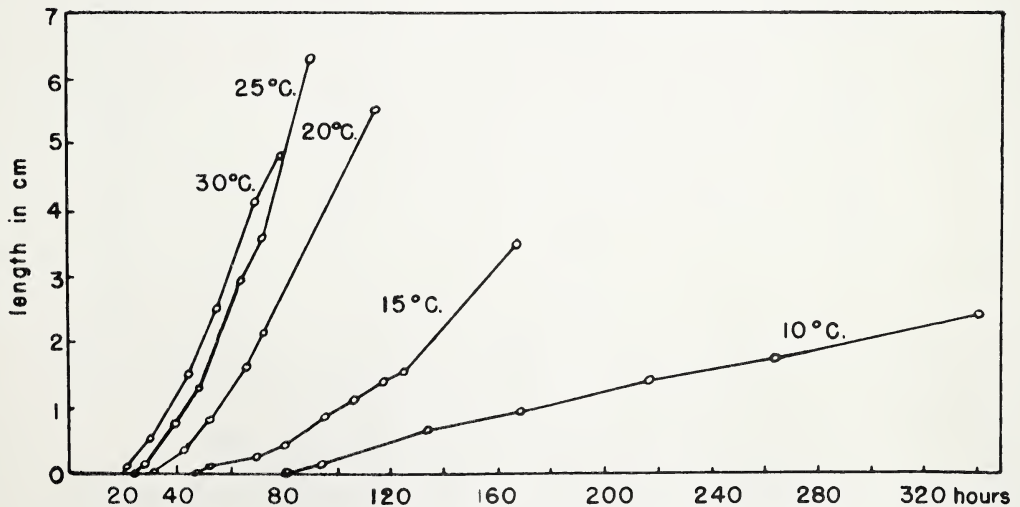


Fig. 11. Increase in length of Tartary buckwheat seedlings at different temperatures

At 38° C., the highest temperature used, some seeds germinated and grew until five days after the beginning of the test, after which time the sprouts died.

Fig. 11 shows the rate of elongation of buckwheat seedlings at different temperatures. There was little difference in elongation rate in the temperature range 20° - 30° C. At 15° C. the process took place much more slowly, and at 10° C. it was extremely slow.

3. Effect of planting depth on emergence

A summary of the results obtained is presented in Table XI.

Table XI. Emergence of Tartary buckwheat seedlings from different depths in the soil.

Planting depth	Maximum % emergence	Days to first emergence	Days to maximum emergence
1"	93	7	9
2"	87	8	10
3"	91	8	12
4"	83	9	14
5"	48	12	17
6"	24	16	23
8"	0	-	-

The data presented are average figures, based on the results of several experiments, between which there was considerable variation, especially at the greater planting depths. Emergence from the six-inch depth was nil in one case, and amounted to 48 percent in another

experiment. When, in one of the pot experiments, the soil was carefully washed away with a stream of water, it was found that the percentage germination at a depth of six inches was only slightly lower than at one or two inches below the soil surface. Many of the seedlings from six inches deep had come to within about one inch of the soil surface, but failed to grow the whole distance.

4. Effect of planting date on emergence

Table XII shows the emergence following planting of Tartary buckwheat seeds at different dates throughout the growing season of 1957.

Table XII. Effect of planting date on the emergence of Tartary buckwheat seedlings.

Planting date	Maximum % emergence	Days to maximum emergence	Remarks
May 16	-	12 ⁺	cutworm damage
May 30	66	27	dry weather
June 14	92	15	
July 1	100	10	
July 16	94	7	
July 29	90	10	
August 14	96	12	
August 28	93	8	

Under the conditions of the experiment seeds would germinate and grow at any time during the growing season, provided that enough moisture was available.

5. Flowering and seed production

Seed production by weedy plants is an important factor to be considered in making recommendations for control, especially where seeds are chiefly responsible for spreading of the weed, as is the case with Tartary buckwheat.

During both 1956 and 1957 observations were made on Tartary buckwheat plants, growing in field plots, to obtain data on the progress of flowering and seed production. The data obtained from these observations and from yield determinations are summarized in Table XIII.

Table XIII. Progress of flowering and seed production of Tartary buckwheat plants.

	Planting date					
	1956			1957		
	May 18	June 21	July 19	May 17	June 8	July 1
Maximum % emergence	80	87	91	-	82	96
Days to maximum emergence	11	13	7	-	14	10
Days to first flower	39	37	-	46	35	37
Days to first immature seed	53	50	42	54	45	42
Days to first mature seed	77	70	62	79	68	62
Days to harvest (Sept. 17 -20)	122	88	63	-	101	78
Lb./A. total dry weight	8995	5186	3681	-	-	-
Lb./A. seed yield	5093	2516	704	-	2049	1360
% mature seed	74.8	58.6	8.7	-	-	-

Flowering began five to six weeks after planting, irrespective of the date of planting, and the first seeds matured four to five weeks later, or a total of nine to eleven weeks after planting. The earliest plantings resulted in much greater yields of seed and total dry matter than did those at the later date. The latest planting in 1956 (July 19) produced 704 pounds of seed per acre, but only 8.7 percent of this was mature seed.

Plants of Tartary buckwheat are very susceptible to frost, and in both 1956 and 1957 flower and seed production on all plots was stopped by frost during the latter half of September.

The progress of seed maturation is shown by data presented in Table XIV. Since the last planting failed to produce any mature seed before the first fall frost, the results of only the first two plantings are included.

Table XIV. Progress of seed maturation on Tartary buckwheat plants.

Planted June 8		Planted July 1	
Days after planting	% mature seeds	Days after planting	% mature seeds
61	0	59	0
68	1.1	66	0.7
75	4.8	73	5.9
82	11.7	78	20.8
89	20.8	-	-
96	52.0	-	-
101	65.0	-	-

On the plots seeded earliest the percentage mature seed increased from 1 to 65 percent over a period of approximately five weeks. If the plants had been able to grow for a longer period of time, this percentage would probably have gone up to at least 75 percent or more (see Table XIII). The total number of seeds per plant varied considerably, and for the first planting ranged from 400 at 68 days to 1100 at 89 days after planting, depending largely on the size of the individual plant. The percentage of mature seeds appeared to be independent of the total number of seeds present on a plant.

In order to determine the effect of spraying with 2,4-D on seed production and seed viability Tartary buckwheat plants were treated with LV 2,4-D at six and twelve oz/A. at two different growth stages; at stage 1 the plants were four inches high and had six to seven leaves, while at stage 2 the plants were ten to twelve inches high, and some flowers and a large number of flower buds were present on them. The buckwheat plants were far enough advanced in growth stage not to be killed by any of the treatments, though growth was slowed down or stopped entirely for at least a short period as a result of the application of LV 2,4-D. Records made at harvest time in the fall are presented in Table XV.

The "abnormal" seeds were smaller than the other seeds, and were very much flattened longitudinally. In cross section they were no longer triangular, but shaped somewhat like a very flat ellipse. Results of periodic germination tests indicated that the abnormal seeds were perhaps slightly slower in losing their dormancy, but had as high a viability as did the normal-appearing seeds. After five

Table XV. Seed production of Tartary buckwheat plants treated with LV 2,4-D at 6 and 12 oz./A. at two stages of development (vegetative and early flowering).

Treatment	Stage	Straw yield lb./A.	Seed yield lb./A.	% mature seeds	% abnormal mature seeds ⁺
Check	-	3488	2966	76.1	0.4
LV 2,4-D 6 oz./A.	1	2592	2032	73.6	6.4
LV 2,4-D 12 oz./A.	1	2384	1400	57.0	4.9
LV 2,4-D 6 oz./A.	2	2592	2142	77.0	10.0
LV 2,4-D 12 oz./A.	2	2656	1949	72.9	9.7
L.S.D. 5%		320	251	7.0	3.7

⁺ Based on total number of mature seeds.

weeks of dry storage at room temperature both normal and abnormal seeds from all treatments germinated 92 - 99 percent.

Field plantings of normal and abnormal seeds the following spring resulted in an equally high percentage emergence for both, and the plants produced appeared normal in all respects.

6. Discussion and conclusions

The experimental results indicate that seeds of Tartary buckwheat germinated over a wide range of temperature, although at the lower end of the range the process took place much more slowly. At 10° C., for example, emergence from pots did not reach a maximum until 18 days after planting.

Shoots were sent up from depths up to six inches, although many seedlings failed to reach the soil surface from this rather critical depth, presumably as a result of an insufficient supply of reserve food materials. The fact that some seedlings did emerge, however, makes doubtful the value of attempts to control Tartary buckwheat by deep cultivation.

There was no evidence of any periodicity in germination of Tartary buckwheat seeds, since seedlings were produced at any time during the 1957 growing season. The rate of germination and emergence was determined largely by the soil temperature, and the variability of this factor is presumed to be responsible for the varying number of "days to maximum emergence" in Table XII. Seeds shattered from buckwheat plants in the fall might conceivably behave differently than uniform seeds planted at different times throughout the growing season.

Because of the indeterminate flowering habit of Tartary buckwheat (32, 41), flowers, immature seeds, and mature seeds may all be found present on the same plant at any given time during at least a part of its growth period. The data obtained for "days to first flowering" and "days to first mature seed" correspond rather closely to those reported by Quisenberry and Taylor (41). Flowering began five to six weeks after planting, and flowers continued to develop on new shoots until the first frost. The first mature seeds were found present on the plant four to five weeks after the beginning of flowering. In one experiment the percentage of mature seeds increased from 1 to 65 percent over a period of approximately five weeks. Given a longer growing period

(cut short in the writer's experiments by cutworms in the spring, and frost in the fall of 1957), seed maturation will take place over a longer period of time, and a greater percentage of mature seeds will be attained.

The data in Table XIII indicate that with a later planting date the time from planting to the first mature seed became shorter. This observation can be explained by the findings of Skok and Scully (47), who reported that short photoperiods promoted floral development and fruit production on Tartary buckwheat plants. Visual observations by the author also substantiated their conclusion that the shorter photoperiods occurring later in the summer favoured lateral shoot development over elongation of the main axis. Plants grown from seed planted at the later dates (July 19) were considerably more bushy than those from the earlier plantings.

Spraying with LV 2,4-D of buckwheat plants bearing flower buds resulted in decreased yields of straw and seed, and the production of a number of seeds of abnormal appearance (Table XV). Treatment at stage 1 was most effective in stunting the plants, but corresponding treatments at stage 2 resulted in the production of almost twice as great a percentage of abnormal seeds. This result is not surprising since a large number of flower buds were present on the plants at the time the second treatment was applied. The percentage of normal seeds was relatively low, because new shoots, developed after the plants recovered from the spraying treatment, produced normal flowers and seeds.

The abnormal seeds were equal in viability to normal-appearing seeds, and upon planting in the field developed into plants which were normal in all respects. The results did not support the possibility of effecting the production of abnormal seeds, which are not viable, by treating the plants with hormone-type herbicides at the flower-bud or flowering stage.

III. Chemical Control and Effects of Competition

1. Materials and methods

Unless stated otherwise, the Tartary buckwheat seed was planted approximately one inch deep in rows, using a V-belt seeder. Rows were ten feet long, and spaced six to twelve inches. By using measured amounts of seed for each plot uniform stands were obtained, permitting reliable comparisons between treatments. Plots were of sufficient size to eliminate any border effect at harvest time.

Barley was the cereal used in all field tests involving treatments with herbicides. It was seeded at the same depth as the buckwheat, using a Columbia seeder. In the 1956 experiment each plot contained two rows of barley in the center, with two rows of buckwheat on either side, forming a total of six rows per plot, spaced one foot apart. The realization that this type of arrangement was not the best for comparison with actual conditions in the farmer's field, led to the choice of an alternating row design in one 1957 experiment. In this design each plot contained four rows of barley alternated with three rows of buckwheat. Where the competitive effect of Tartary buckwheat in barley was investigated, all rows were spaced nine inches apart, with the buckwheat rows being at right angles to the barley rows. Sufficient buckwheat seed was planted to result in stands of various desired densities, following thinning by hand.

To study competition between Tartary buckwheat plants alone in a field experiment, seed was broadcast on 5' x 5' plots, and then covered with approximately one inch of soil. Following emergence the

plots were thinned by hand to obtain the desired densities. In a greenhouse study buckwheat seeds were planted in seven-inch pots filled with a 3:1 mixture of black loam and sand. The number of pots was large enough to permit yield determinations in triplicate at different times following planting.

The experimental design of the field experiments was of the "split plot" type in all cases where both grain and Tartary buckwheat were included in the experiment. The number of replicates was three or four.

The chemical treatments were applied using a sprayer head clamped to the top of a milk bottle. Each bottle contained the amount of chemical required for treatment of one plot, mixed with an amount of water equivalent to 50 - 75 gal./A. Spraying was done at a pressure of 30 - 35 p.s.i., using a portable air compressor driven by a gasoline engine.

2. Comparison of the effects of various herbicides

In a 1956 experiment plots containing both Tartary buckwheat and Olli barley were treated with single and double applications of ester-formulations of MCPA (Methoxone), 2,4-D (Weedone), and LV 2,4-D (Weedone LV 4). The first application consisted of dosages of 0, 4, 8, and 16 oz./A. of these three chemicals, and was followed twelve days later by a second application consisting of check (no treatment), MCPA at 4 oz./A., 2,4-D at 4 oz./A., and LV 2,4-D at 4 oz./A. The number of plots was sufficient to provide in triplicate all possible combinations of first and second treatments (48 in all). At the time of the first

application (20 days after planting) the buckwheat plants had three true leaves, and were two inches high, while the barley had three to four leaves, and was seven inches high. When the second application was made, the buckwheat was seven to eight inches high, and the barley fifteen to sixteen inches.

When the Tartary buckwheat plants on the check plots were beginning to set seed (33 days after first spraying), one row of buckwheat was harvested from each plot, and the fresh weight determined immediately. On September 5 (110 days after planting) another row of Tartary buckwheat was harvested, and the seed yield was determined. The fresh weight and seed yield data are presented in Table XVI, while Fig. 12, in graphical form, shows the fresh weight data, expressed as percentages of the fresh weight of the check plot.

Barley yield could not be determined on all plots because of bird damage. The results obtained indicated, however, that the yield of a treated plot was in no case lower than that of a weedy check plot. Yields of treated plots ranged from 4 to 37 percent higher than those of check plots.

Because the experiment was designed, and the results analyzed as a three-factor split-plot type, there was a large number of possible comparisons and corresponding L.S.D. values. It seemed unnecessary and possibly confusing to add these values to the ones presented in Table XVI.

In a 1957 field experiment the esters of 2,4-D (Weedone), LV 2,4-D (Weedone LV 4), and 2,4-DB (butyl (2,4-dichlorophenoxy) butyrate)

Table XVI. Fresh weight and seed yield in lb./A. of Tartary buckwheat from plots given one application or two (12 days apart) of MCPA, 2,4-D, and LV 2,4-D

Chemical	Treatment (1) Rate	Fresh weight in lb./A.				Seed yield in lb./A.			
		One treatment (1)	Two treatments (1) + 4 oz./A. of:			One treatment (1)	Two treatments (1) + 4 oz./A. of:		
			MCPA	2,4-D	LV 2,4-D		MCPA	2,4-D	LV 2,4-D
Check	-	29,770	26,529	24,248	20,407	4995	3973	3145	2437
MCPA	4 oz./A.	18,246	12,844	12,604	11,404	3517	2425	1777	1885
2,4-D	4 oz./A.	13,685	9,483	8,763	6,002	3121	1777	1645	1356
LV 2,4-D	4 oz./A.	13,204	6,122	9,483	6,962	2761	1236	1080	984
MCPA	8 oz./A.	12,844	7,923	6,482	4,561	2281	1681	1500	1140
2,4-D	8 oz./A.	3,961	1,560	2,521	1,440	1224	564	564	456
LV 2,4-D	8 oz./A.	1,681	600	1,200	840	1116	156	204	60
MCPA	16 oz./A.	840	720	480	360	1140	360	120	360
2,4-D	16 oz./A.	840	240	240	240	396	204	204	204
LV 2,4-D	16 oz./A.	40	0	0	0	120	228	84	120

Mean square values from analysis of variance

First treatment:	Chemicals	49.7	44,288*
	Rates	4374.6**	534,122**
	Chemicals x Rates	92.9	5,348
Second treatments		160.3**	93,692**
Second treatment x chemicals first treatment		3.3	692
Second treatment x rates first treatment		27.4**	11,744**

* Significant at 5% point

** Significant at 1% point

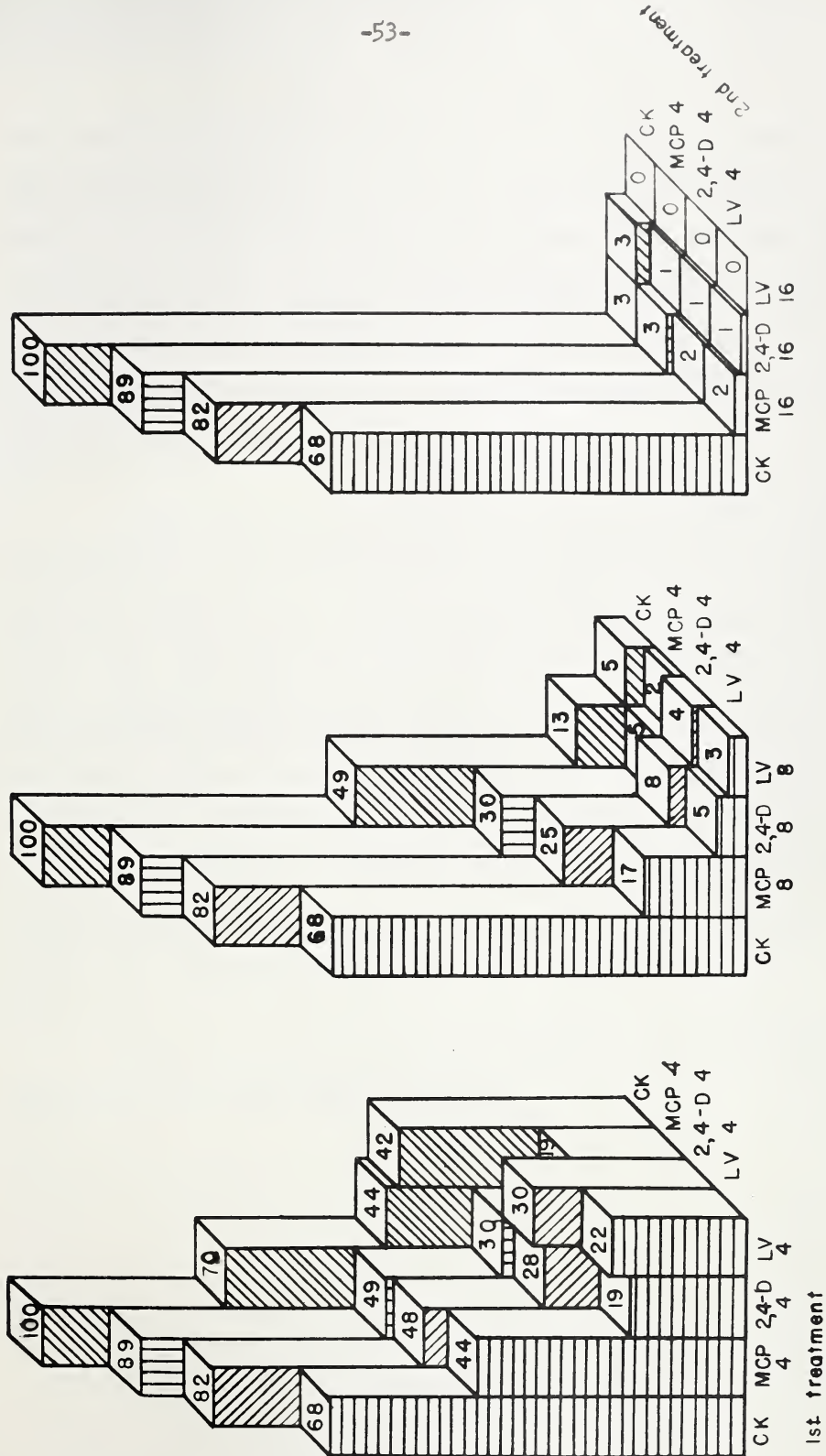


Fig. 12. Fresh weight of Tartary buckwheat, expressed as percentage of check, from plots given single and double applications of MCPA, 2,4-D and LV 2,4-D

were compared at different rates and at two stages of application. Also included was neburon (3-(3,4-dichlorophenyl)-1-methyl-1-n-butylurea), a more recently developed herbicide which had shown promising results in the control of Tartary buckwheat elsewhere (36). The chemical 2,4-DB was included because it causes less injury to the grain, though in a preliminary test it appeared less effective on the weed than 2,4-D at comparable rates.

When the first application was made (14 days after planting), the first true leaf of the buckwheat was just beginning to unfold, while the barley (variety Gateway) had two leaves, and was four to five inches tall. Ten days later when the buckwheat had four true leaves, and the barley had five leaves (seven inches tall), another application was made on plots not treated previously. Two rows of barley and one row of Tartary buckwheat were harvested on September 16 for yield determinations. The number of buckwheat plants in the row harvested was determined both prior to spraying and at harvest time. The results obtained are presented in Table XVII.

The check plot did not yield sufficient grain for the determination of the bushel weight of barley.

Table XVII. Yields of barley and Tartary buckwheat, bushel weight of barley, and survival of Tartary buckwheat plants in a comparison of the effects of several herbicides.

Treatment		Barley				Tartary buckwheat			
		Yield bu./A.		Bu. wt. lb./bu.		Tot. dry wt. lb./A.		Seed yield lb./A.	
Chemical	Rate	Stage 1	Stage 2	Stage 1	Stage 2	Stage 1	Stage 2	Stage 1	Stage 2
Check	-	15.2	12.6	-	-	4453	4957	1168	1536
2,4-D	4 oz./A.	45.9	30.2	46.4	45.4	1320	3013	336	708
2,4-D	8 oz./A.	40.9	35.9	45.9	47.2	632	1940	172	480
2,4-D	12 oz./A.	36.7	39.6	45.3	46.1	716	1324	216	336
LV 2,4-D	4 oz./A.	38.2	36.5	46.4	46.8	1468	2849	392	576
LV 2,4-D	8 oz./A.	34.4	34.2	44.5	46.1	448	2409	108	544
LV 2,4-D	12 oz./A.	36.7	36.7	44.6	46.3	648	1248	224	500
2,4-DB	8 oz./A.	45.7	40.9	45.3	46.2	808	1704	288	396
2,4-DB	16 oz./A.	47.5	38.2	45.4	45.1	456	1368	124	220
2,4-DB	24 oz./A.	49.0	41.5	45.3	46.4	372	640	128	232
Neburon	2.5 lb./A.	52.8	37.3	45.1	45.9	680	3685	276	1064
Neburon	5 lb./A.	50.0	32.6	44.3	46.1	0	3013	0	888
Neburon	10 lb./A.	44.2	36.7	44.6	44.6	0	84	0	16
L.S.D. Interaction	5%	8.1		no significant			672	271	10
L.S.D. Treatments	5%	13.6		difference			2076	539	51

Mean Square Values from Analysis of Variance

		Barley		Tartary buckwheat	
		Stages	Error I	Treatments	Error II
Stages		52,261	23,470	13,234*	11,668**
Error I		23,470	24,430**	4,877	351
Treatments		4,055*	4,055*	54,456**	3,039*
Treatments x Stages		1,569	1,569	9,423**	837**
Error II				1,182	41

* Comparison of treatments within one stage

** Significant at 5% point

** Significant at 1% point

3. Effects of competition

Competition always occurs where two or more plants make demands for light, nutrients, or water in excess of the supply (56). The results are generally manifest in smaller plants. In a preliminary greenhouse experiment it was found that increasing numbers of Tartary buckwheat plants per six-inch pot resulted in reduced stem diameter, leaf width, and number of leaves per plant (Table XVIII).

Table XVIII. Effects of competition between Tartary buckwheat plants grown in pots in the greenhouse.

Plants per pot	23 days after planting			72 days after planting		
	Stem diameter mm.	Maximum leaf width cm.	Leaves per plant	Fresh weight grams per plant	Total seeds per plant	% mature seeds
1	4.0	6.3	13.0	42.0	373	40.5
3	3.2	5.3	6.5	10.3	98	44.1
5	2.9	4.4	4.5	6.4	56	43.4
10	2.1	4.2	4.5	3.1	28	39.1
15	2.0	3.7	4.0	2.6	21	40.5

In another greenhouse experiment Tartary buckwheat was grown in seven-inch pots, at 1, 2, 4, 8, 16, and 32 plants per pot. On an area basis one plant per seven-inch pot is roughly equivalent to 25 plants per square yard. The number of pots was sufficiently great to allow the harvesting of triplicate sets of pots at five different times following planting. Some of the results obtained are presented in Table XIX.

Table XIX. Effect of competition between Tartary buckwheat plants on their production of seed and total dry weight.

Data Presented	Plants per pot	Days after planting									
		40	53	81	95	109	40	53	81	95	109
		Grams per pot					Grams per plant				
Total dry weight	1	0.09	0.47	6.0	10.5	16.2	0.09	0.47	6.00	10.5	16.2
	2	0.36	2.02	10.0	10.3	16.0	0.18	1.01	5.00	5.15	8.00
	4	0.44	2.70	14.3	16.9	21.4	0.11	0.68	3.58	4.22	5.35
	8	0.97	5.02	16.1	23.7	13.9	0.12	0.63	2.01	2.96	1.75
	16	1.69	4.83	14.9	19.9	25.1	0.11	0.30	0.93	1.24	1.57
	32	2.48	7.24	13.0	23.8	27.2	0.08	0.23	0.41	0.74	0.85
		Seeds per pot					Seeds per plant				
Number of seeds	1	0	8	240	403	440	0	8	240	403	440
	2	0	35	418	382	568	0	18	209	191	284
	4	0	63	556	659	819	0	16	139	165	205
	8	0	109	603	903	570	0	14	75	113	71
	16	0	157	637	831	1072	0	10	40	52	67
	32	0	187	556	957	1118	0	6	17	30	35
		% mature seed (ave. of all pots)									
		-	0	38	78	94					

In 1957 two field experiments were undertaken to obtain some quantitative data on the competitive effect of Tartary buckwheat, alone or with barley. The effect of spraying with LV 2,4-D on competition was also determined.

The results of the experiment with buckwheat alone are presented in Table XX. Material was harvested from one quadruplicate set of plots at each of two stages. At the first stage (68 days after planting) the first seeds were just beginning to form, while at the second stage (100 days after planting) the majority of the seeds present were mature.

Table XX. Fresh and dry weight, and seed yield of Tartary buckwheat growing at different densities.

Stage	Plants per sq. yd.	Total fresh weight		Total dry weight		Yield of mature seeds	
		lb./A.	gm./plant	lb./A.	gm./plant	lb./A.	gm./plant
1	25	30,410	114	3073	11.5	0	-
	50	29,769	56	2774	5.2	0	-
	100	39,159	37	3628	3.4	0	-
	200	40,759	19	3724	1.7	0	-
2	25	25,715	96	5484	20.6	1643	6.1
	50	28,382	53	5815	10.9	1793	3.4
	100	27,208	26	6039	5.7	2347	2.2
	200	26,568	12	5772	2.7	2497	1.2

The relative size of buckwheat plants grown in plots with different numbers of plants per square yard is shown in Fig. 13. With increasing density the plants grew somewhat taller, but they were more spindly, and showed much less branching.



Fig. 13. Representative Tartary buckwheat plants from plots containing 25, 50, 100, and 200 plants per square yard (L - R).

The second experiment included both Tartary buckwheat and barley (variety Gateway). Soon after emergence the buckwheat was thinned by hand to obtain quadruplicate sets of four plots with 0, 25, 50, and 100 plants per square yard. The objective of this experiment was to determine the effect on grain yield of weed competition, spraying with LV 2,4-D, and the interaction of these two factors.

At the time the treatments were applied (21 days after planting) the barley was approximately six inches high and had four to five leaves, while the buckwheat had two to three true leaves. The results of determinations made at harvest time are presented in Table XXI. The percentage survival of buckwheat plants was determined by counting the number of plants on one square yard in each plot, and comparing it to the number present before treatment. Fig. 14 illustrates graphically the barley yield and the total dry weight of buckwheat.

Visual observations during the growing season indicated a slight delay in heading, and the failure of a number of barley heads to emerge properly, on plots sprayed with LV 2,4-D at both rates.

Table XXI. Yields of barley and Tartary buckwheat from plots containing different numbers of buckwheat plants per square yard.

Treatment	Buckwheat plants per square yard	Barley		Tartary buckwheat		
		yield bu./A.	bushel weight lb./bu.	total dry weight lb./A.	Seed yield lb./A.	% survival
Buckwheat plants removed by hand at spraying time	0 25 50 100	69.9 71.2 69.7 57.6	46.2 44.3 44.6 44.5	- 0 0 0	- 0 0 0	- 0 0 0
Check (no treatment)	0 25 50 100	68.6 64.0 49.1 27.9	46.2 45.0 45.1 43.6	- 1387 2185 3271	- 179 393 751	- 89 88 82
LV 2,4-D at 8 oz./A.	0 25 50 100	62.3 59.6 51.9 43.8	45.0 45.8 44.3 44.4	- 18 75 117	- 2 17 31	- 9 21 16
LV 2,4-D at 12 oz./A.	0 25 50 100	60.1 51.3 48.6 41.3	44.1 43.6 43.7 43.3	- 8 18 55	- 1 5 12	- 3 8 7
L.S.D. Interaction	5%	8.3	-	174	75	-
L.S.D. Densities	5% \nearrow	20.8	-	-	492	-
L.S.D. Treatments	5% $\nearrow\nearrow$	19.6	1.7	1596	488	9

Mean Square Values from Analysis of Variance

Densities	226,622**	5.74	49,584**	4,599**	77
Error I	32,251	1.60	910	154	70
Treatments	131,559*	6.23*	725,687**	27,008*	19,227**
Treatments x densities	21,530**	1.46	40,689**	3,814**	58
Error II	4,772	1.46	689	129	37

\nearrow For comparison of densities given the same treatment
 $\nearrow\nearrow$ For comparison of treatments on the same density.

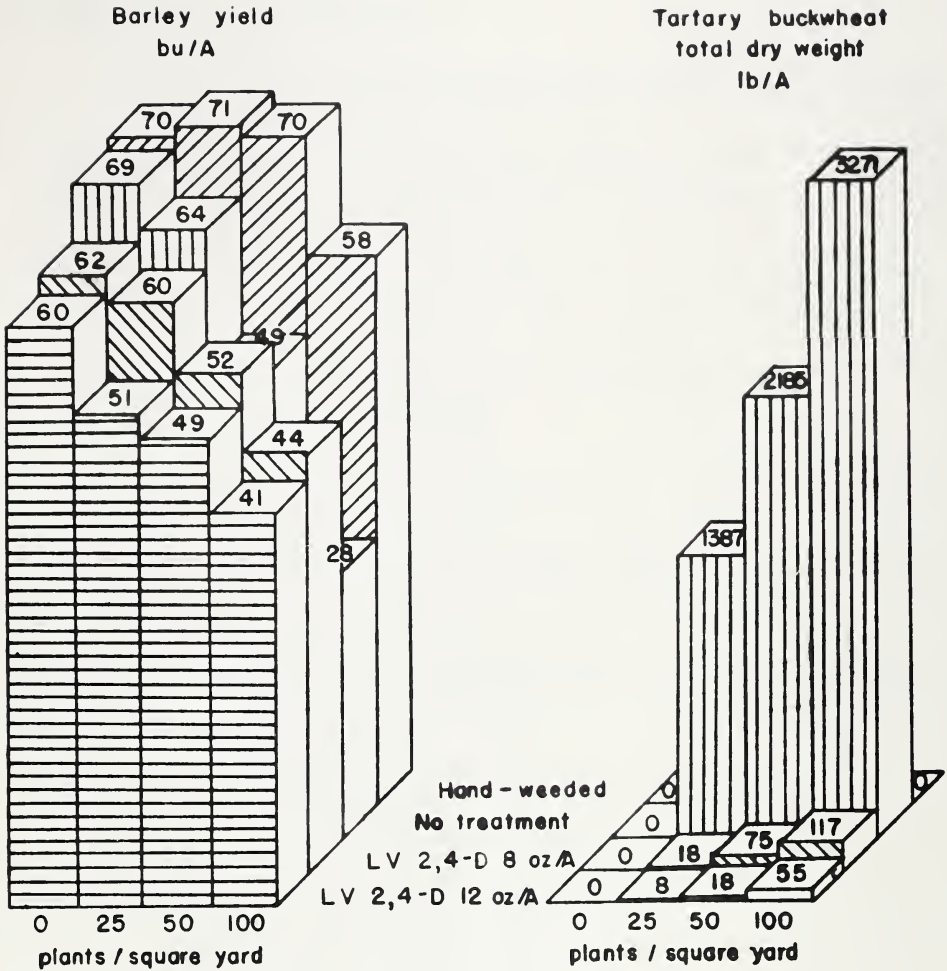


Fig. 14. Yields of barley and Tartary buckwheat from plots containing different numbers of buckwheat plants per square yard

4. Discussion and conclusions

When considering data obtained from small-plot experiments on weed control, it must be recognized that the results do not always necessarily correspond to those obtained in a farmer's field infested with weeds. The advantages of the small plots with an artificial weed infestation are evident, however, in that a uniform stand of both weeds and crop plants may be obtained, permitting reliable comparisons between the effects of different treatments.

Weather conditions are a factor which may be responsible for a large part of the variability in results obtained in different years. These conditions first of all influence directly the effect of herbicides on the plant, and are especially important in their effect on the results of weed competition experiments. For example, in a year with plenty of available moisture crop yields may not be affected by the competition for water of a given weed population, while in a drier year the same population may seriously reduce the yield of grain. Obviously it is very difficult, if not impossible, to duplicate these conditions in different years and at different locations. This difficulty explains, at least partly, the variability in results obtained by different weed workers, and the necessity of extensive repetition of experiments.

From the experimental results obtained previously by a number of weed workers it had become clear that control of Tartary buckwheat by chemical methods is a goal difficult to achieve (36, 38). Eradication required dosages of herbicide which caused serious injury to the grain. There remained considerable scope for research to determine

optimum rates of chemicals and times of application or possible economic advantages in dealing with weed infestations of different intensities.

In both 1956 and 1957 various chemicals were compared at Edmonton with regard to their effect on Tartary buckwheat growing in a crop of barley. Examination of the buckwheat data obtained reveals first of all a very consistent relationship between fresh weight and seed yield in 1956 (Table XVI, Fig. 12), and between total dry weight and seed yield in 1957 (Table XVII). In both cases, therefore, these groups of data will be considered together.

Of the chemicals used in the first treatment (Table XVI) 2,4-D and LV 2,4-D were superior to MCPA at the 4 and 8 oz./A. rate, while at 16 oz./A. there was no marked difference. Grouping the chemicals together, the 8 oz./A. rate was more effective than 4 oz./A., while the 16 oz./A. rate was significantly better than 8 oz./A. only in the case of MCPA. Of the second treatments LV 2,4-D was most effective; there was not much difference between 2,4-D and MCPA. Grouping all comparisons together, it appeared that LV 2,4-D was more effective than 2,4-D, and that both were much superior to MCPA. The difference was most pronounced at the 8 oz./A. rate of first treatment, and where the second treatment was applied on previously untreated plots.

In the 1957 experiment (Table XVII) LV 2,4-D and 2,4-D were about equally effective at both times of application in reducing buckwheat growth, but LV 2,4-D applied at growth stage 1 was more injurious to the barley, and the result was a lower yield. The chemical 2,4-DB appeared much less injurious to the barley than did 2,4-D, and at 8 oz./A. was as effective as the latter in reducing the buckwheat stand.

Highest barley yields and maximum control of buckwheat were obtained following application of neburon at stage 1. The higher rates caused some leaf burning on the grain. At the later stage of application this chemical was much less effective, and only the highest rate (10 lb./A.) resulted in satisfactory control. The results with neburon were promising in that 100% kill of the buckwheat could be obtained without causing serious injury to the barley. For practical use, however, the cost of this chemical is still prohibitive. Also, further experiments must be carried out with regard to possible residual effects. Results of a preliminary greenhouse experiment showed that neburon was ineffective as a pre-emergence herbicide for the control of Tartary buckwheat.

The percentage survival of Tartary buckwheat plants following treatment with LV 2,4-D at 8 oz./A. in one 1957 experiment was 9 - 21 percent, while the 12 oz./A. rate resulted in a slightly greater proportion of the plants being killed (Table XXI). Corresponding survival data in another experiment were 32 and 25 percent (Table XVII), i.e., survival was greater even though the buckwheat was sprayed at an earlier growth stage. The explanation for this difference may be found in the greater competition of barley as a result of less space between the rows, and cross-seeding of the buckwheat in the former experiment. These experimental conditions seem to more closely approximate actual field conditions, and would therefore form a more reliable basis for recommendations.

Double applications of herbicide have been reported to be effective in the control of wild buckwheat (Polygonum convolvulus) (36). In an experiment in which the effect of a second application

of herbicides to Tartary buckwheat was investigated at Edmonton in 1956, the effects of two separate doses of 4 oz./A. may be compared with those of a single 8 oz./A. application (Table XVI, Fig. 12). In almost every case repeated applications (12 days apart) were less effective than a single application at a correspondingly higher rate, made at the earlier growth stage.

Competition between Tartary buckwheat plants followed the same trend as that found for other species (56). Total amount of vegetative matter and seed produced per unit area were fairly constant for different plant densities. For individual plants these values decreased sharply with increasing number of plants per unit area (Tables XVIII and XIX). Where two plants were growing together in a seven-inch pot (Table XIX), there appeared to be no serious competition until almost 80 days after planting, as indicated by the total dry weight and number of seeds per plant at 53 and 80 days after planting.

The results of the field experiment (Table XX) were similar to those obtained in the greenhouse. At stage 2 fresh weights were lower, and dry weights higher than at stage 1. This difference may be explained by the presence on the plant of a large number of mature seed with a relatively low moisture content at stage 2.

In discussing the competition between Tartary buckwheat and barley (Table XXI, Fig. 114) it must be recognized that the quantitative conclusions drawn may be considered valid only under the conditions of the experiment. Burrows and Olson (6) found that wild mustard affected the growth of wheat before the latter had reached the five-leaf stage

of growth. In the writer's experiment the barley had four to five leaves at spraying time, and up to 50 buckwheat plants per square yard at that time had not yet affected the yield of barley. At 100 plants per square yard the buckwheat population had already caused enough damage through competition to cause a yield decrease of approximately 12 bu./A. If the buckwheat plants were present throughout the growing season, 25 plants per square yard caused a marked reduction in grain yield (4.6 bu./A.), and a buckwheat density of 100 plants per square yard reduced the grain yield to 40 percent of that of a weed free plot. It might be noted that at the greatest density (100 plants per square yard) the total dry weight of buckwheat produced on the check plot (Table XXI) was about half of that produced on plots containing Tartary buckwheat alone at the same density (Table XX).

Chemical treatment decreased the yield of barley on weed free plots and on plots containing 25 buckwheat plants per square yard. Apparently in the latter case the injury of the herbicide to the barley had a greater effect on the yield than did the lessened weed competition. The yield of barley decreased with increasing buckwheat density, but did so much more rapidly on the check plots than on plots treated with LV 2,4-D at 8 oz./A. Treatment with LV 2,4-D at 12 oz./A. resulted in somewhat better control of buckwheat, and relatively more crop injury, the net result being a lower barley yield in all cases.

Burrows and Olson (6) found that the critical density of wild mustard plants, at which spraying with 2,4-D could be considered justifiable, depended on the rate of seeding of grain, and was higher for a higher rate of seeding. For buckwheat-infested plots sprayed with

LV 2,4-D at 8 oz./A. in the writer's experiment the critical density appeared to lie somewhere between 25 and 50 plants per square yard.

Though treatment of plots containing 25 buckwheat plants per square yard with LV 2,4-D at 8 oz./A. resulted in a barley yield lower than that of the untreated plot, this yield reduction need not necessarily be considered a loss. The presence of Tartary buckwheat seeds in wheat or malting barley seriously lowers the commercial grade of these products (51). In the experiment described none of the buckwheat plants on plots sprayed with LV 2,4-D reached a height greater than six or seven inches. At harvest time it should be possible to avoid getting any parts of those plants into the harvester. Though the surviving stunted buckwheat plants do produce some viable seed, the grain harvested does not need to be contaminated with those seeds, and the somewhat lower yield of clean grain is likely to be more profitable than a higher yield of grain contaminated with buckwheat.

The importance of spraying early in the season was indicated by the results of experiments in both 1956 and 1957. From Table XX (page 58) it is evident that in all except two cases the percentage survival of Tartary buckwheat was much higher following treatment at the second stage than at the first. Not only did fewer plants survive treatment at the earlier stage, but those that did were stunted much more severely than survivors of treatment at the second stage. This conclusion may be drawn from the much greater proportional difference between first and second stage values for buckwheat yield than between corresponding values for percentage survival, and was confirmed by visual observations. Although the barley yield data showed no

significant difference between stages, the yield following first stage treatment was highest in all except two cases (2,4-D and LV 2,4-D at 12 oz./A.). By the time the plants had reached the stage of growth at which the second application of chemical was made, weed competition had already had a serious effect in lowering grain yield.

There was a definite relationship between the degree of weed control, the amount of herbicidal injury caused to the grain, and the grain yield obtained. A greater degree of weed control resulted in less weed competition, and the crop plants were given the chance to produce a higher yield, though this effect was at least partly counteracted by increased injury to the grain.

From the data presented it appears that the best chemical treatment for control of Tartary buckwheat is an application of LV 2,4-D, early in the season, at 8 oz./A. or as much as the crop will tolerate. Although the series of rates included in the field experiments was by no means complete, the results indicated that within limits the effects of a given treatment with LV 2,4-D could also be obtained by applying "standard" ester at a somewhat higher rate. Under practical conditions, for example, an application of 2,4-D at 8 oz./A. might result in the same degree of weed control as LV 2,4-D at 6 oz./A., but cause less injury to the crop. If the weeds and crop plants are in a very young stage of growth at spraying time, there may be no advantage in using LV 2,4-D rather than the standard ester. As the growth stage advances, however, and the weeds become more resistant, the advantages of LV 2,4-D become more evident.

The first part of the paper is devoted to a general discussion of the problem of the origin of life. It is shown that the problem is not only a scientific one, but also a philosophical one. The scientific aspect of the problem is concerned with the question of how life arose from non-life. The philosophical aspect is concerned with the question of whether life is a necessary part of the universe or whether it is a mere accident.

The second part of the paper is devoted to a discussion of the various theories of the origin of life. It is shown that there are three main theories: the theory of spontaneous generation, the theory of panspermia, and the theory of abiogenesis. The theory of spontaneous generation is the oldest and simplest, but it is also the least plausible. The theory of panspermia is the most plausible, but it is also the most difficult to test. The theory of abiogenesis is the most recent and most complex, but it is also the most promising.

The third part of the paper is devoted to a discussion of the evidence for the origin of life. It is shown that there is a great deal of evidence in favor of the theory of abiogenesis. This evidence includes the discovery of the fossil record, the discovery of the chemical evolution of life, and the discovery of the genetic code.

The fourth part of the paper is devoted to a discussion of the implications of the origin of life. It is shown that the origin of life has important implications for our understanding of the universe and for our understanding of ourselves. It is also shown that the origin of life has important implications for the search for life on other planets.

Eradication of Tartary buckwheat at present is evidently impractical, but with the methods and treatments discussed it is certainly possible for the farmer to keep this weedy species under control.

SUMMARY

1. Freshly collected mature seeds of Tartary buckwheat, regardless of time of collection, were dormant, and failed to germinate immediately.
2. Impermeability of the seed coat to water or gases was not entirely responsible for dormancy. No evidence of the presence of a growth-inhibiting substance was found.
3. Various chemical treatments, or stratification at 5° C. or 10° C. for up to six months did not overcome seed dormancy. Results of stratification at a lower temperature were inconclusive.
4. Mature seeds lost their dormancy in approximately six months when kept in a refrigerator at 2° - 3° C., but required only four to five weeks at room temperature, or two weeks in an electric oven at 40° C., to achieve comparable results.
5. Drying mature seeds at 80° C. for 24 - 72 hours was effective in overcoming dormancy. To achieve comparable germination results, fresh seeds required a longer exposure than did seeds which had been stored dry at room temperature for one week.
6. In overcoming dormancy heating the seeds to 60° C. for 24 hours in a stoppered glass vial was as effective as heating them to 80° C. in an open one, provided that the initial moisture content of the seeds in the closed vials was not high enough to cause injury. The after-ripening process apparently was accelerated by high temperature, and the accompanying loss of moisture was merely incidental.

7. More rapid after-ripening of dormant seeds in stoppered glass vials than in open ones, both kept at room temperature, indicated the existence of an optimum moisture content for after-ripening at that temperature. The optimum value was in the range of 15 - 20 percent moisture.
8. Immature seeds in all cases lost their dormancy much more slowly than did mature seeds, and then did not attain as great a percentage germination.
9. Air-dry, non-dormant Tartary buckwheat seeds could tolerate exposure to temperatures of up to 90° C., if they were allowed to dry out during the treatment. The seeds were easily injured at 50° or 60° C. if a higher initial moisture content was maintained throughout the treatment.
10. The seeds germinated over a wide range of temperatures, though more slowly at the lower end of the range. Shoots were sent up by seeds planted up to six inches deep in the soil. Seeds germinated and produced seedlings at any time during the 1957 growing season.
11. Flowering began five to six weeks after planting, and the first seeds matured four to five weeks later. Flower development and seed maturation continued until stopped by frost in the fall.
12. The spraying with LV 2,4-D of buckwheat plants bearing flower buds resulted in the production of a number of abnormal seeds. The abnormal seeds were equal in viability to normal-appearing seeds, and on planting produced plants which were normal in all respects.

13. For control of Tartary buckwheat there was no advantage in using two applications of herbicide, twelve days apart, rather than a single application at a correspondingly higher rate. At comparable rates LV 2,4-D was more effective than 2,4-D, especially at the later growth stages, and both were much superior to MCPA for the control of Tartary buckwheat.
14. In competition between Tartary buckwheat plants total production of straw and seed was relatively independent of the plant density; single-plant yields decreased sharply with increasing number of plants per square yard.
15. Under the conditions of the experiment up to fifty buckwheat plants per square yard had not yet, during the time before spraying, affected the ultimate yield of barley. On sprayed plots there was a balancing effect between herbicidal injury to the grain, and decreased weed competition. The effect of the interaction between these two factors was manifested in the yield of grain.

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